PERIODICAL ROOM
GENERAL LIBRARY
UNIV. OF MICH.

JUN 28 1928

THE JULY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

BASAL METABOLISM: THE MODERN MEASURE OF VITAL ACTIVITY. DR. FRANCIS G. BENEDICT 5

THE FUN OF BEING A SCIENTIST. DR. J. O. PERRINE 28

THE MOST INTERESTING WILD ANIMAL IN AMERICA. EDWARD R. WARREN 33

A VISIT TO THE MUD-VOLCANOES OF TURBACO, COLOMBIA. ALBERT C. SMITH 42

SIR ISAAC NEWTON ON GRAVITATION. PROFESSOR FLORIAN CAJORI 47

THE RADIOACTIVE ELEMENTS. DR. I. R. KOLLER 54

SHIPS. PROFESSOR EZRA BOWEN 57

FOOD PREJUDICES. DR. CHARLES W. TOWNSEND 65

AGRICULTURAL MAGIC. GRACE M. ZIEGLER 69

BIRDS AND OTHER CHECKS UPON INSECTS. W. L. MCATEE 77

SPECIALIZATIONS GOVERNING MUSICAL EXPRESSION AMONG INSECTS. H. A. ALLARD 81

THE PROGRESS OF SCIENCE:

Hideyo Noguchi; Edgar Fahs Smith; The Arnold Arboretum of Harvard University 89

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

RECENT BOOKS OF SCIENTIFIC INTEREST

with comments by the publisher

Apes and Men, 138 pp.; **Hunters and Artists,** 150 pp.; **Peasants and Kings,** 145 pp.; **Priests and Kings,** 202 pp. HAROLD PEAKE and H. J. FLEURE. $2.00 each. Yale University Press.

The first four volumes in a series of eight published under the general title of "The Corridors of Time," presenting a survey of human history.

The A B C of Flight. W. LAURENCE LEPAGE. 141 pp. $1.50. John Wiley & Sons, New York.

The reader is taken through the entire theory of the flight of an airplane. In the simplest possible manner the construction and operation of the aircraft engine are dealt with; there is also a chapter on flying instruction.

The Geography of the Polar Regions. OTTO NORDENSKÖLD and LUDWIG MECKING. 340 pp. $4.00. American Geographical Society, New York.

The first part discusses in general climate, ice, the Ice Age, soils and landforms, vegetation and animal life of the polar regions. The second is a description of the Arctic and Antarctic, written according to modern geographical standards.

The Biology of Insects. GEORGE H. CARPENTER. 464 pp. $6.50. Macmillan Company, New York.

In this volume the insect's structural features are described only so far as seems necessary for the understanding of function and behavior, while questions of systematic entomology are discussed in their relation to problems of ecology and evolution.

The Role of Scientific Societies in the Seventeenth Century. MARTHA ORNSTEIN. 283 pp. $3.00. University of Chicago Press, Chicago.

A history of science, scientific societies and institutions; describing the backgrounds for the achievements of our modern scientists; for those who are interested in general history as well as in the progress of science.

The Indiana Sand Dunes and Shore Lines of the Lake Michigan Basin. GEORGE B. CRESSEY. 80 pp. $2.00. University of Chicago Press. Chicago.

The object of this book is to explain the origin of the dunes and is largely a discussion of the principles of eolian activity and the evolution of the Indiana portion of Lake Michigan since the retreat of the last ice sheet.

Health and Wealth. LOUIS I. DUBLIN. 361 pp. $3.00. Harper & Brothers, New York.

The economic approach to the problem of public health is the distinguishing feature of this book. The author, as statistician of the Metropolitan Life Insurance Company, speaks from an intimate knowledge of the effects of the newer health work.

Elementary Bacteriology. JOSEPH E. GREAVES and ETHELYN O. GREAVES. 506 pp. $3.50. W. B. Saunders Company, Philadelphia.

A narrative of early ideas regarding bacteria and the work of the pioneers in the field, followed by a study of the actual organisms and the relation of bacteria to the life of man.

Max von Pettenkofer. EDGAR ERSKINE HUME. 142 pp. $1.50. Paul B. Hoeber, New York.

An evaluation of Pettenkofer's theory of the etiology of cholera, typhoid fever and other intestinal diseases, together with a biographic sketch and a brief consideration of his researches along lines other than epidemiological.

Psychological Care of Infant and Child. JOHN B. WATSON. 187 pp. $2.00. W. W. Norton & Company, New York.

This book on child psychology contains chapters devoted to the care of the infant at day and night, to the growth, control and range of temper tantrums, and to the problem of sex instruction.

The Soils of Cuba. H. H. BENNETT and R. V. ALLISON. 410 pp. $6.25. Tropical Plant Research Foundation, Washington.

The book presents a soil survey of the entire island of Cuba. It defines all the 80 important soil types and shows their distribution. The crop adaptations, fertilizer needs and vegetative features of each soil type are individually discussed.

Aladdin U. S. A. ERNEST GREENWOOD. 265 pp. $2.50. Harper & Brothers, New York.

In this book there is set forth a record of the development and accomplishments of electricity. The changes which it has brought into our daily lives, its social, industrial and political influences are discussed.

The Mental Life. CHRISTIAN A. RUCKMICK. 248 pp. $2.00. Longmans, Green & Company, New York.

A survey of the fundamental facts of the science of psychology, written to meet the demands of the intelligent layman and for use in elementary college courses. An extensive bibliography is added for those wishing further detailed study.

The Care of Ornamental Trees. C. F. GREEVES-CARPENTER. 65 pp. $1.25. Macmillan Company, New York.

A pocket-sized manual for the owner of trees and those who take care of them. It gives brief directions for tree surgery: filling cavities, bracing, cabling, pruning, fertilizing, planting, spraying and care of all ornamental trees.

The books noted above may be obtained at the publisher's regular rates from THE SCIENCE PRESS DISTRIBUTING COMPANY, Grand Central Terminal, N. Y. (See page ix.)

THE SCIENTIFIC MONTHLY

THE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

VOLUME XXVII
JULY TO DECEMBER

NEW YORK
THE SCIENCE PRESS
1928

Copyright, 1928
THE SCIENCE PRESS

THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA.

THE SCIENTIFIC MONTHLY

JULY, 1928

BASAL METABOLISM: THE MODERN MEASURE OF VITAL ACTIVITY[1]

By Dr. FRANCIS G. BENEDICT

DIRECTOR, NUTRITION LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

THE search of the ancient philosophers for the philosopher's stone or the elixir of life has been fruitless down through the centuries. If, instead of searching for the elixir of life, these men had sought an explanation of life processes, they would have made much greater progress, for in the past hundred years the elaborate studies which have been made in biophysics and biochemistry have explained the mechanistic features of life reasonably clearly. Thus, although the philosopher's stone remains unfound, life has been bettered and prolonged by the fundamental knowledge gained regarding its chemistry and physics.

The early investigators were not wholly indifferent to the importance of knowing what happens in the body during the processes of life, however. As early as the third century, B. C., Erasistratus made observations upon the insensible perspiration of hens and other fowls. That is, he made crude measurements of their loss in body weight and the weights of their food and excreta. At about the time when our Pilgrim fathers were landing in America, Sanctorius, of Padua, conceived the idea of weighing himself from hour to hour upon a special balance, thus being the first to obtain a quantitative measurement of the loss in body weight which is going on continuously in all living beings, with periodic gains due to food and drink. His investigations of the insensible perspiration with this crude method covered over thirty years. As a result of his findings he published a curious book of aphorisms, the greater number of which are wholly speculative but a few of which indicate that he had obtained marvelously clear conceptions of certain vital processes. For instance, he found that the loss in body weight is greatest when one is awake and has had food and that the larger person has the larger loss, findings which conform wholly to our present-day notions.

Sanctorius was followed by other investigators, but there was practically no scientific outcome from these long, tedious researches, and the study of the invisible loss in body weight remained dormant from his time until about 1900, when it was taken up again by Professor Warren P. Lombard, of Ann Arbor. Professor Lombard devised an extraordinarily accurate balance for this purpose and laid the foundations for the more recent work by the Nutrition Laboratory, in which the loss in body weight from hour to hour and, indeed, almost from minute to minute has been studied.

[1] Address delivered at the Carnegie Institution of Washington, Washington, D. C., April 18, 1928.

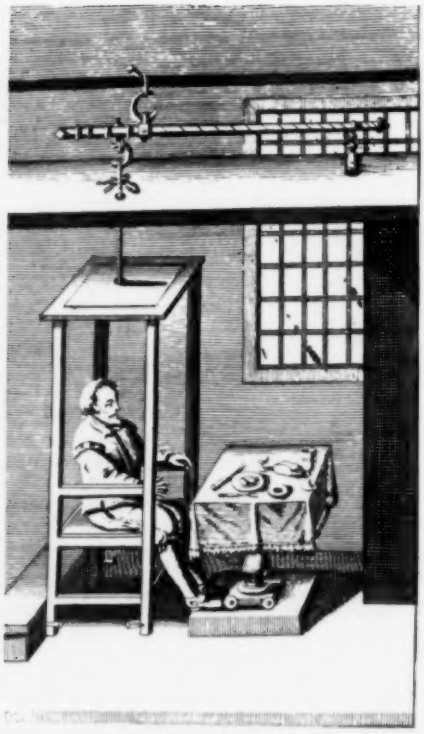


FIG. 1. SANCTORIUS OF PADUA DETERMINING HIS INSENSIBLE LOSS IN BODY WEIGHT.

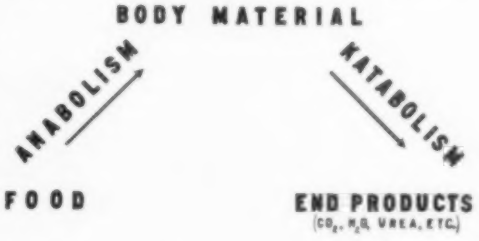
This invisible loss in body weight, due chiefly to the loss of water vapor from the lungs and skin, has been found to be closely related to the main factors of life processes. For our first knowledge of the quantitative relations of these factors we are indebted to the great French savant, Lavoisier, who, nearly one hundred and fifty years ago, studied the chemistry of respiration with a technique marvelously in advance of anything conceived prior to his time and approximating with singular closeness much of the present-day technique. Lavoisier was the first to point out that all life processes are accompanied by the production of carbon dioxide and the absorption of oxygen by the lungs and the liberation of heat from the body. His measurements of the lung gases of man and his measurements of the heat actually given off by small animals represent the first steps in the acquisition of knowledge regarding human and animal metabolism, knowledge upon which our modern conception of nutrition is based.

A century of intense effort followed the unfortunate death of Lavoisier, and culminated in the classic experiments of Rubner with the dog and Atwater with humans. In these experiments a calorimeter was employed, an apparatus which, as the name implies, measures directly the heat given off from the body and, provided it is a respiration calorimeter, measures also the carbon-dioxide excretion and the oxygen absorption of the lungs. The experiments by Atwater with the respiration calorimeter at Wesleyan University in Middletown, Connecticut, showed that

FIG. 2. THE MEASUREMENT OF THE INSENSIBLE PERSPIRATION OF HUMANS.

with man the heat output, the carbon-dioxide elimination and the oxygen absorption are so closely related that by measuring these along with certain other factors it is possible to determine the intensity of vital activity. The experiments may be called "balance experiments." The object of such experiments is best illustrated by considering man as a bank. His food and drink and the oxygen which he absorbs from the air represent his income or his deposits. The urine and feces which are excreted, the water vapor lost from the skin and lungs and the carbon-dioxide exhaled represent the outgo or the withdrawals from the bank. The balance between these deposits and withdrawals or between the income and outgo can be measured in terms of energy by means of calorimeters. If there is no draft upon body material, obviously the energy of income and outgo should balance. If they do not balance, the difference in energy is a measure of the drafts upon or additions to the body stores. Atwater's findings along this line show that the law of the conservation of energy obtains even in as complex a system as the human body. Vitalism as such played no rôle in these experiments, for Atwater was considering *matter* and energy. But the most important outcome of these complete balance experiments was the finding that the carbon-dioxide production, the oxygen consumption and the heat output (which Lavoisier had shown to be the result of life processes) are so closely correlated with each other that in order to determine the level of vital activity one need no longer use the complicated, expensive, time-consuming calorimeter for measuring the heat elimination, but can measure the oxygen consumption alone (a measurement calling for a far simpler technique) and therefrom calculate the heat production.

It was natural that the heat output rather than the oxygen consumption should have been the first factor to be measured, since it is evident that all warm-blooded animals are constantly giving off heat. Each adult is giving off about as much heat as a 100-watt electric lamp. If such a lamp were placed in each chair in a lecture hall, for example, the lecturer and the audience would soon be aware of a feeling of heat from each of these sources. The fact that the heat in the lamp is concentrated, however, makes it difficult to compare it with the heat given off by an individual. We have all had the experience of trying to unscrew an electric light bulb from a



METABOLISM

FIG. 3.

fixture immediately after turning off the current, and we know that the bulb can be extremely hot. If one had a large lens or burning glass and could focus the heat given off by the body down to such a fine point as that represented by the lamp, then the heat output of the individual would be found to equal that given off by the 100-watt lamp. But our body temperature is essentially constant. If heat is lost from the body, heat must also be produced. What regulates the production of heat and what factors most profoundly affect it? Under ordinary conditions there are two distinct phases in the processes of life, (1) the building up of body material from food material (anabolism) and (2) the

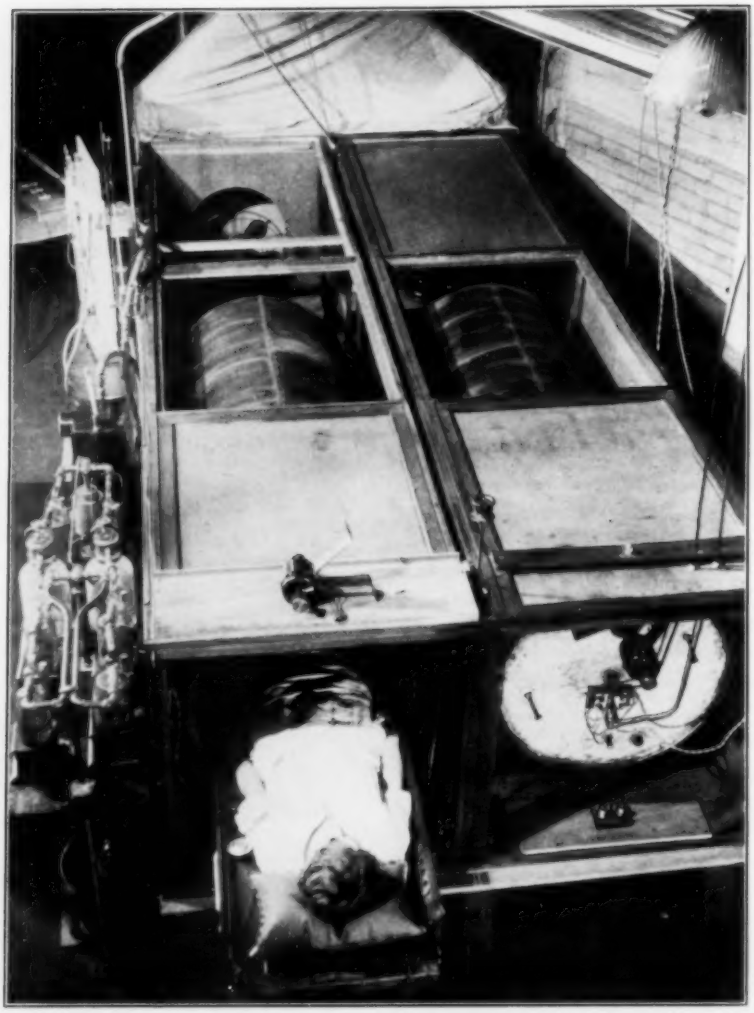


FIG. 4. A SO-CALLED "EMISSION CALORIMETER" FOR MEASURING THE HEAT PRODUCTION OF HUMANS.

breaking down and oxidation of this body material into its end products, chiefly carbon-dioxide, urea and allied compounds (katabolism).

In common parlance no distinction is made between the words "anabolism" and "katabolism," because almost invariably we are considering katabolism. When we speak of a study in metabolism, therefore, we mean usually a study of katabolism, that is, the breaking down of body material, and it is in this phase that heat is developed.

One of the earliest conceptions of the reason for heat production was that the body must be warm in order to function properly and that heat is produced *to keep the body warm*. The body is ordinarily in an environment much cooler than the body temperature. It is thus constantly losing heat to the environment, and in order to keep the body

cells at the proper temperature heat must be produced. This view considers heat production as the *main object* of the chemical processes in the body. Another conception is that heat is a *waste* product, given off *as the result* of muscular motions or chemical transformations arising for an entirely different purpose. We need not go into an extensive analysis of the various lines of reasoning leading to these conceptions, except to point out the two main facts that we are producing and giving off heat all the time and that we all have a body temperature which is essentially uniform. But the fact that the normal body temperature is in general constant does not signify by any means that all individuals have the same heat production. Because all houses are heated to 70° F. does not mean that the same amount of coal is burned in each cellar, for houses differ in size and construction. Similarly with man, the differences in vital activities mean differences in heat production.

One of the first things learned in the study of vital activity was that heat is not produced solely to keep the body warm. It is the result of life processes, an end product or, we might say, a waste product. As the boiler, in order to produce power, must give off a large amount of heat, so is human heat production likewise necessary in order to furnish motive power for human activities. The relations between the power plant and the production of work interest the engineer extremely, but the heat production of man and its relation to vital activity, indeed physical activity, interest us all because we are producing heat all the time. The economist is soon to be as much interested in the heat production and productive labor of man as he is in the efficiency of the newer types of power plants.

It was found with the calorimeter experiments twenty-five years ago that large individuals have a greater heat production than small individuals, although all have essentially the same body temperature. It was also found that the eating of food increases the heat production and that muscular activity, particularly, increases it enormously. Accurate metabolism studies to determine the effect of any special factor can not be made, therefore, unless the conditions of study are the same in all cases. Each animal, even in repose and without food, is continually producing heat—at a low rate, to be sure, but at a rate commensurate with the low vital activity under such conditions. This low heat production, measured under certain reproducible conditions, has been called the "basal metabolism." The conditions considered prerequisite for the measurement of this basal metabolism are that one should be in complete mental and muscular repose, usually after lying thirty minutes on a couch, neither too cold nor too warm, but comfortably relaxed, at least twelve hours after the last meal (which should not have been too rich in protein), with a normal body temperature, and awake. The metabolism would be even lower during sleep and still lower during prolonged fasting, but it is impossible to insure that all individuals will sleep during the period of measurement and fasting is undesirable.

In the early days of metabolism measurements the necessity for ruling out all controllable factors affecting metabolism was not recognized. A certain degree of movement was allowed. The periods of measurement were several hours long and not sharply defined, and the measurement often included both the metabolism during repose and that during moderate activity. The gross factors can be studied fairly well with the calorimeter, but the calorimeter is sluggish in action, designed for long periods of measurement, and transitory

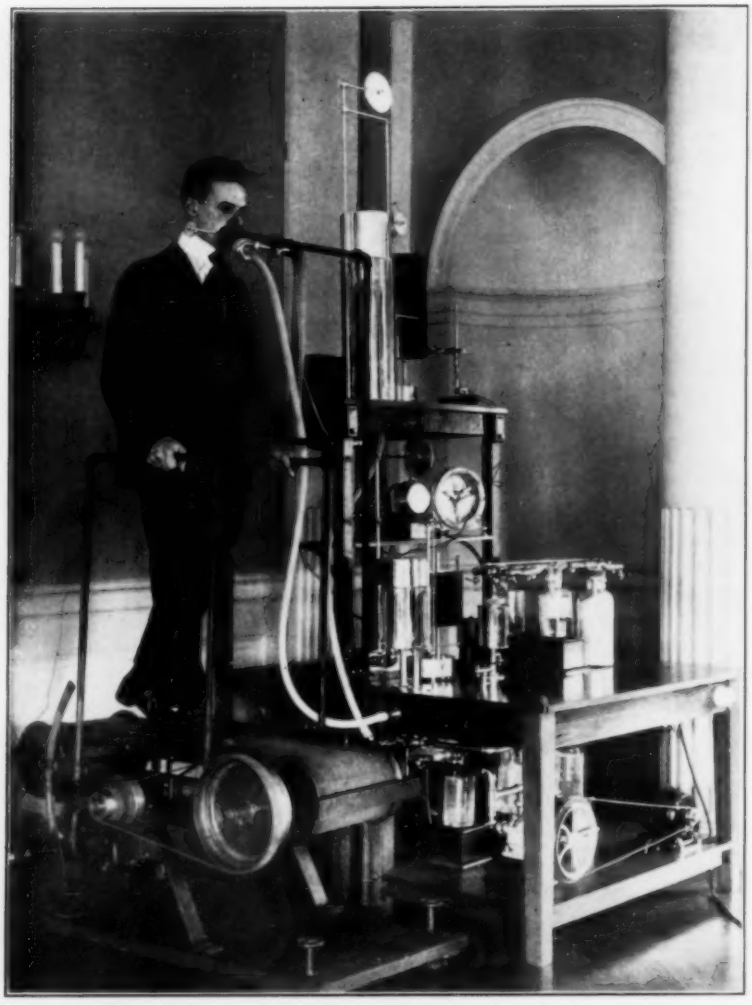


FIG. 5. MEASURING THE HEAT PRODUCTION DURING WALKING.

effects can not easily be recorded. Furthermore, the calorimeter is costly and difficult to operate, requiring a staff of highly trained operators. Fortunately, however, since calorimeter experiments have demonstrated the close relationship between the heat production and the respiratory exchange, it is now possible to obtain a good index of vital activity by measuring either the carbon-dioxide production or the oxygen consumption alone. Respiration apparatus for such measurements can be secured at an inconsiderable expense and require the service of but one technician. Short periods are possible with the respiration apparatus, and hence any transitory changes in metabolism can be measured. The determination of the carbon-dioxide production is not difficult, for the carbon-dioxide in the expired air can be collected and weighed, or the air expired can be analyzed for its carbon-dioxide content. Indeed the carbon-

dioxide output of man or animals is as easily measured as the engineer measures the gases in the chimney flue of the power plant. For years this measurement of the carbon-dioxide production was that most commonly used as an index of vital activity. Later on it became just as easy, in fact, easier, to measure the oxygen consumed by a man, and the newer forms of respiration apparatus are for the most part constructed for the measurement of the oxygen consumption alone.

In these forms of apparatus the carbon dioxide produced is absorbed by soda-lime and the reduction in the volume of air in the closed circuit is measured either by the fall in height of a spirometer bell or by the amount of oxygen to be introduced into the closed circuit to bring the volume of the system back to its original point. The spirometer bell is the dominant feature in the laboratory apparatus in most general use.

The oxygen consumption is a somewhat more accurate measure of the heat production than is the carbon dioxide exhaled. Since each liter of oxygen used in metabolism is accompanied by a heat liberation of about five calories, the heat production can be easily computed from the measured volume of oxygen consumed. The measurement of the heat production has thus become a simple process, now available to every student in the physiological laboratory.

The establishment of simple methods of measurement and the recognition of the necessity for reproducible basal conditions made possible studies on the influence of many different factors upon vital activity. Is the basal metabolism constant from hour to hour? From day to day? How is it affected by sleep, by ingestion of food and by muscular work, all factors entering into every one's daily life? These problems

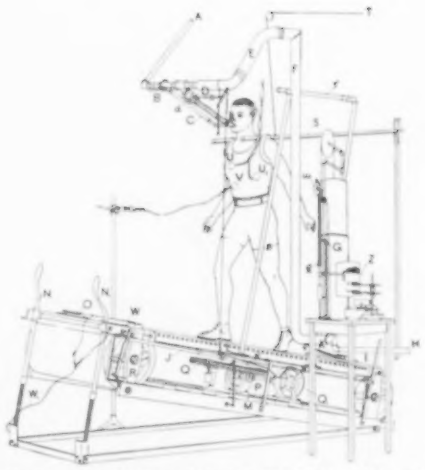


FIG. 6. SCHEMATIC OUTLINE OF APPARATUS FOR DETERMINING THE HEAT PRODUCTION DURING WALKING.

can all obviously be studied with one person. But in the broader field of comparative physiology it becomes necessary to study different individuals, and then the effects of body size, weight and height, age and sex must be determined.

TABLE 1

CONSTANCY IN BASAL METABOLISM IN CONSECUTIVE 10-MINUTE PERIODS

(Mr. C., January 26, 1925)

Period	Oxygen consumed per minute
	cc.
I	219
II	220
III	219
IV	230
V	223
VI	225
VII	225
VIII	229
IX	223
X	223
XI	222

More recently race has also been suggested as a potential factor affecting metabolism, and here again the study must be made with numbers and not with a single individual.

Countless respiration experiments dealing with these and other problems

FIG. 7. RECENT MODEL OF APPARATUS FOR DETERMINING THE OXYGEN CONSUMPTION OF A HUMAN.

have now made certain facts in the field of metabolism sufficiently clear to permit of discussion. Thus, it has been found that the basal metabolism of the same individual remains reasonably uniform on any one day and likewise from day to day, when the conditions of measurement are the same.

It will be of interest to note what is the effect, for example, of the ingestion of food upon this fairly constant basal metabolism. In a typical series of measurements made before and after the ingestion of one hundred grams of cane sugar the oxygen consumption prior to the eating of the sugar was two hundred cc per minute, and twenty-five minutes after the sugar was eaten it had increased to 244 cc. This finding is of special importance, since it indicates the necessity for avoiding any stimulus to digestion during the period of basal metabolism measurement.

TABLE 2

CONSTANCY IN BASAL METABOLISM ON CONSECUTIVE DAYS.—MR. C.

Date	Oxygen consumed per minute
	cc.
April 21	217
" 22	215
" 23	214
" 24	218
" 25	229
" 28	222
May 5	216
" 10	225
" 19	221
June 24	226
" 25	219

Muscular work has a still more pronounced effect than the ingestion of food. Even small muscular movements affect the basal metabolism, and by severe muscular work the metabolism may be increased tenfold. The accompanying photographs show the method of studying the metabolism of a man during the severe muscular work of walking on a treadmill at a rapid rate or working at a drill press. In our consideration of basal metabolism such studies are of the greatest significance in showing the necessity for avoiding any muscular activity. Complete muscular repose is imperative.

Having seen that the eating of food is accompanied by an almost immediate

FIG. 8. A HEAD CHAMBER OR HELMET FOR MEASURING THE OXYGEN CONSUMPTION OF A HUMAN.

FIG. 9. MEASURING THE OXYGEN CONSUMPTION OF A MAN WHILE WORKING AT A DRILL PRESS.

increase in metabolism, we naturally ask, "How does the complete withdrawal of food, or fasting, affect the metabolism?" Studies on this point have shown that during fasting the basal metabolism becomes lower and lower each day. One of our subjects (shown in the accompanying photograph) fasted for thirty-one days, and as can be seen from the chart, his heat production throughout this period decreased continuously. It is obvious, therefore, that for the comparison of different individuals the basal metabolism can not be measured after prolonged fasting.

Rarely does the body weight of the individual change to such an extent as the result of fasting to have fasting *per se* enter into any such comparisons. Undernutrition may, however, frequently appear, not only with the same individual, if studied over a long period of time, but with two individuals otherwise comparable, except that one is poorly nourished. Undernutrition results in a marked lowering of metabolism. A group of twelve men, who were subjected for four months to reduced rations amounting to about one half the normal intake, lost twelve per cent. of their body weight and their metabolism fell off 25 per cent. or more. This finding is sufficiently striking to emphasize that the state of nutrition of the body is an important factor in assessing the value of basal metabolism measurements.

Is the decrease in metabolism noted with fasting due specifically to the fasting or, since the individual is smaller at the end of the fast, is it due to the pronounced change in body size? A great many measurements have been made upon people of widely different weights,

TABLE 3

BASAL TWENTY-FOUR-HOUR HEAT PRODUCTION

New-born infant (3.5 kg.)	143 calories
Adult man (70 kg.)	1,700 calories

and values are now available which show that the average new-born baby, weighing 3.5 kg., has a twenty-four-hour basal heat production of 143 calories, the average thirteen-year old girl,

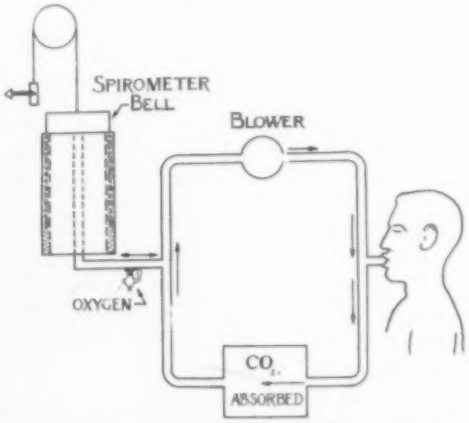


FIG. 10. SCHEMATIC OUTLINE OF APPARATUS FOR MEASURING THE RESPIRATORY EXCHANGE OF MAN.

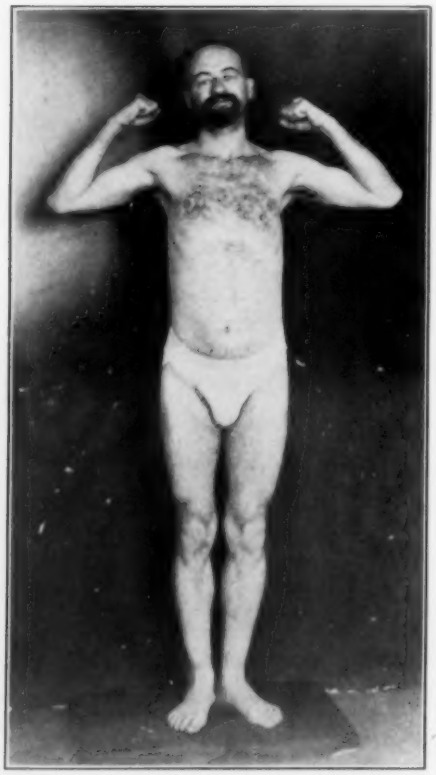


FIG. 11a. BEFORE THIRTY-ONE-DAY FAST.

weighing 42 kg., has a heat production of 1,200 calories, and the average man, weighing 70 kg., has a heat production of 1,700 calories. Thus, the heat production of the small baby, with less than one tenth the weight of the thirteen-year old girl, is considerably more than one tenth of her heat production and one twelfth of the heat production of an adult man weighing twenty times as much. The baby, therefore, has a high heat production per unit of weight. Some attempt to allow for size, however, is logical, and the heat per unit of mass, usually per kilogram of body weight, was computed to be used for the basis of comparison. From such data we have plotted a curve comparing the heat production per kilogram of body weight with the body weight, for new-born infants, boys and men up to 94 kg. in weight. This curve shows that the heat production on this basis increases rapidly up to about 8 kg. and then falls off again, reaching a fairly constant level at 74 kg.

At first it was supposed that two individuals could be compared with each other if they were of the same weight, but it was soon discovered that the tall, thin man has a metabolism different from that of the short, fat man, even if they are both of the same weight. Height is, therefore, another factor which affects metabolism. With weight and height, age is also more or less closely correlated, for low weight and low stature are coincident with youth

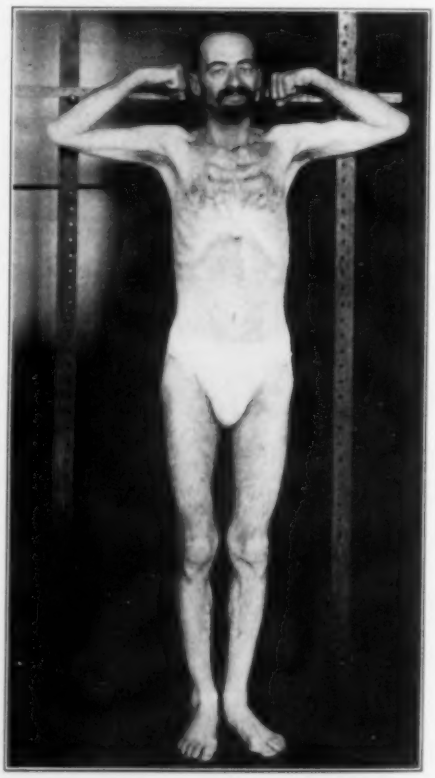


FIG. 11b. AT END OF THIRTY-ONE-DAY FAST.

and greater weight and greater stature with adult life. As the number of basal metabolism measurements gradually increased, it became possible to study the effect of age. Ideally it would be desirable to measure the same individual from birth to old age. That was impracticable. At first most of the measurements were made on people of college age, as it was easiest to obtain volunteer subjects among college students. Later we were able, through the splendid cooperation of Dr. Fritz B. Talbot, of Boston, to study normal children from birth (the babies were often inside of a respiration chamber forty minutes after birth) up to about twelve years of age. There was then a fairly wide gap in the data from the age of twelve to the college age, but the services of the Girl Scouts were enlisted and this gap has now been filled in for girls. Beyond the college age measurements have gradually been accumulated and now, after some twenty years of work, we have a fairly complete series of measurements from birth to old age, the ninety-year period being represented by that Nestor of American surgeons, Dr. W. W. Keen, of Philadelphia, who kindly volunteered to be measured so that the age picture might be complete.

The interpretation of these results then became a problem. How is it possible to interpret the metabolism of a child of one year in such terms as to make it comparable with the metabolism of an adult? Obviously the total metabolism can not be compared directly. We have just seen that the intensity of the metabolism per unit of weight is much greater in youth than in later years. Comparison on this basis, therefore, is only a crude one. Many years ago the conception was originated that heat is lost to the environment in proportion to the surface area of the body. From this conception the belief arose that the heat production per unit of surface area is uniform with all warm-blooded animals. Various methods for estimating the body surface were then tested, the most accurate of which, for humans, is that developed by Dr. E. F. Du Bois, of New York City. Indeed, as the result of a formula, developed by Du Bois, it is now possible, from the measurements of the height and weight, to compute the body surface with considerable exactness. With more careful measurements, both of the basal metabolism and more particularly of the sur-

FIG. 12. MEASURING THE BASAL METABOLISM WITH A FIELD RESPIRATION APPARATUS.

face area, it transpired that the heat production per unit of area shows less variation for different individuals than it does per unit of body weight. But even on this supposedly uniform basis, as will be seen from the accompanying chart, the heat production varies considerably, especially prior to the age of fifteen or sixteen years. Thus, with newborn infants it is very low, 600 calories for each square meter of skin area. But at the age of one year or a weight of ten kilograms it is at the highest point during life. After fifteen years it is nearly uniform. The heat production

When the number of metabolism measurements made by the Nutrition Laboratory on different individuals had increased into the hundreds with both sexes, a biometric analysis of the data was made with the cooperation of Professor J. Arthur Harris, now at the University of Minnesota, but at that time connected with the Department of Experimental Evolution of the Carnegie Institution of Washington. This biometric analysis showed clearly that there are four independent factors closely correlated with metabolism, namely, age, height, weight and sex. From this

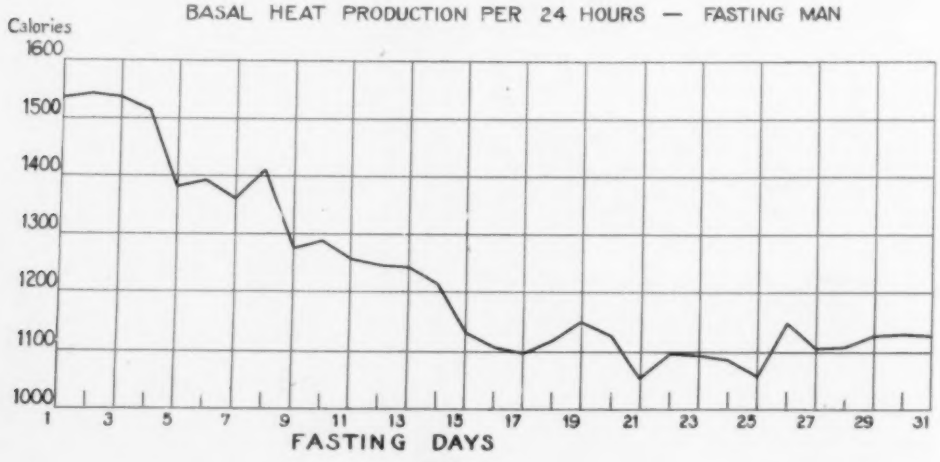


FIG. 13

of different individuals, therefore, whether compared per unit of body weight or per unit of body surface, is seen to vary with age, and the youth has a more intense metabolism than the adult.

These same curves enable us to compare boys with girls and men with women. Up to about one year of age it is seen that there is no difference in metabolism between the sexes. But thereafter the influence of sex becomes pronounced, and the metabolism of men and boys is on the average about 12 per cent. higher than that of women and girls.

analysis formulas have been derived, by means of which it is now possible to predict with reasonable accuracy the probable basal metabolism of adults, knowing the age, weight, height and sex. These prediction formulas are used by many clinicians in comparing the metabolism of pathological individuals with the probable basal metabolism of normal individuals of the same physical characteristics. Du Bois, analyzing much the same data, has also suggested another method of predicting the probable metabolism, from age and body surface. The surface area prediction method is simpler, and if one does not

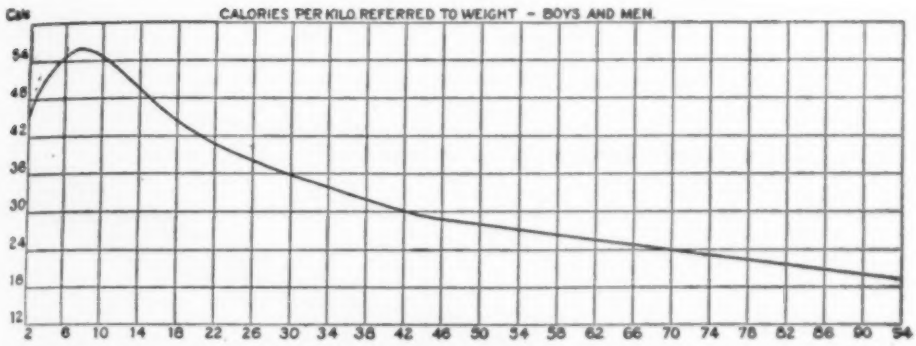


FIG. 14. THE RELATON BETWEEN HEAT PRODUCTION AND BODY WEIGHT.

ascribe too great significance to the relation between the surface area and the loss of heat from the body, the surface area is a practical basis for prediction. These prediction standards serve the purpose fairly well for the majority of the situations confronting the physician, although they are woefully deficient in old age and in early youth. Both of these methods of prediction have been used extensively by clinicians and have been a real help in many instances, but, I am sorry to say, in other instances a false guide, for exactly as the little mark of 98.6° F. on the fever thermometer has been a fetish for decades, so these so-called "prediction standards" of metabolism are becoming fetishes of the experts in metabolism, and too rigid adherence to these standards has not infrequently caused rather serious blunders. It should be recalled that the prediction method is simply an effort to aid the clinician in interpreting the measured metabolism of a patient upon whom no measurements have ever been made when he was not ill. In lieu of such measurements comparison with the predicted normal basal metabolism is the only procedure possible.

Our main theme, however, deals not so much with the prediction of basal metabolism as with the factors affecting it. How resistant is the basal metabolism to superimposed factors? One of the commonest experiences of every one is sleep. Under conditions of sleep one would expect to have the greatest degree of muscular and psychic repose. Hence the influence of sleep on metabolism possesses unusual interest for us. With the type of respiration apparatus ordinarily employed for basal metabolism measurements (see figures 7, 8 and 10),

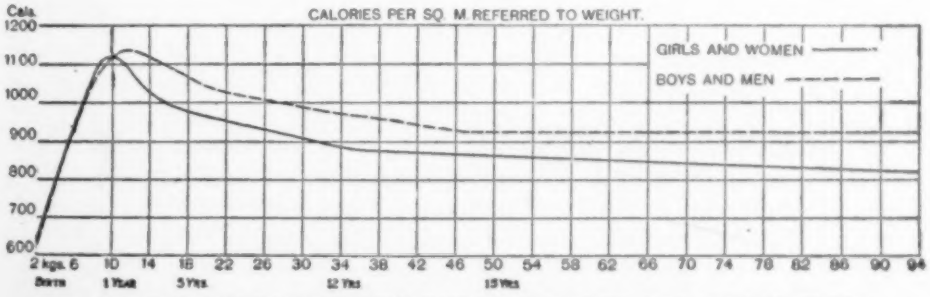


FIG. 15. RELATION BETWEEN HEAT PRODUCTION AND BODY WEIGHT.

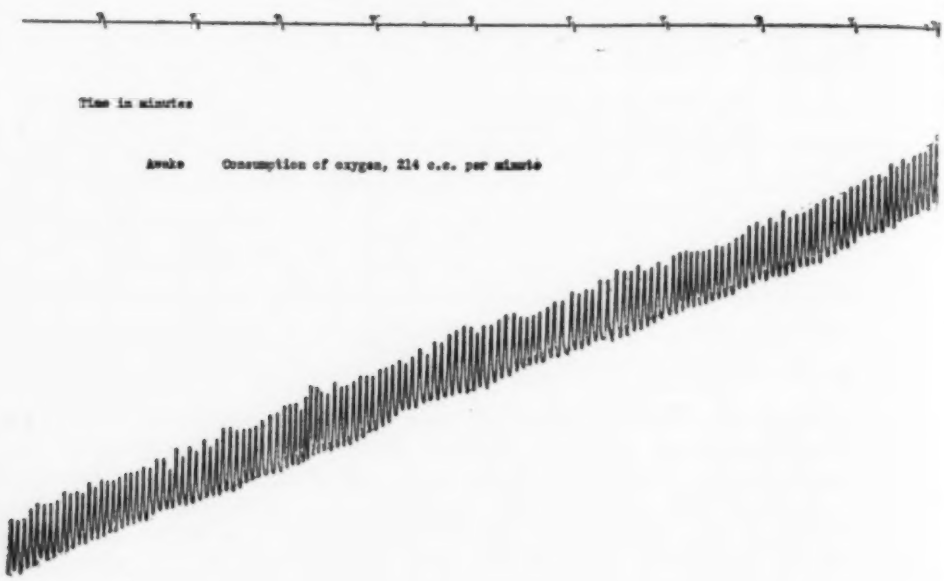


FIG. 16. CURVE OF OXYGEN CONSUMPTION—SUBJECT AWAKE.

the respiratory movements as well as the oxygen consumption of the subject are recorded graphically on paper. When the man is awake, the tracing of the respiration is remarkably uniform, as will be seen from the accompanying chart. When he is asleep, however, the tracings are by no means so regular. The measurements obtained in these two instances are typical of the differences in respiratory mechanics commonly found as a result of sleep. Furthermore, the oxygen consumption per minute, while the subject was awake, was 214 cc and while asleep, 189 cc, a drop of about 10 per cent. Hence, in view of the extremely irregular respiration and the lower metabolic level during sleep, it is clear that for practical purposes and for the reproducible conditions stipulated for basal metabolism measurements values found only when the individual is awake can be used for comparison.

Usually basal metabolism measurements are made while the subject is lying on the back. Is the metabolism any lower when the ordinary position of sleep customary with the individual is assumed? Most people sleep on the right side. It has been argued that the metabolism is actually lower in this position. Recently, however, a series of experiments made with several trained subjects have shown not only that it is *impossible to obtain a lower metabolism* when the subject is lying on the side than when lying on the back, but that

TABLE 4

INFLUENCE OF BODY POSITION ON BASAL METABOLISM

Subject	Lying on	Oxygen (cc.) Consumed per minute	
Mr. A	Back	223, 226, 226	= 225
	Side	223, 226	= 225
Mr. B.	Back	227, 232	= 230
	Side	235, 238	= 237
Miss W.	Back	167, 165, 173	= 168
	Side	173, 178, 174, 173	= 175

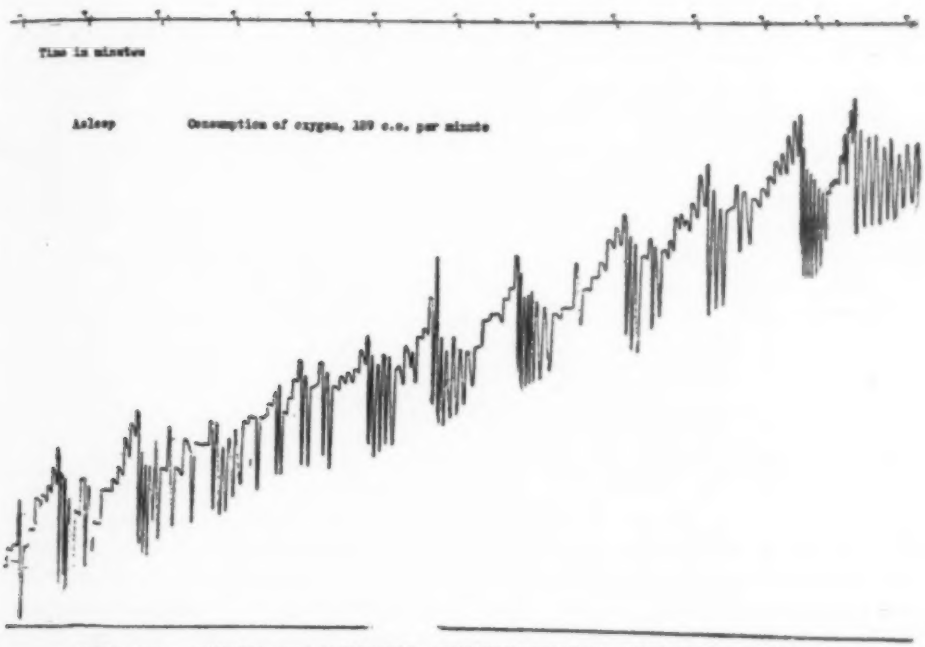


FIG. 17. CURVE OF OXYGEN CONSUMPTION—SUBJECT ASLEEP.

the metabolism is really the lowest when one is lying on the back.

It is a common experience that severe mental work is fatiguing. Most people, when lying on the back, are inclined to mental repose, but the influence of mental activity must be considered in basal metabolism measurements, for we can not stipulate that our subjects should be in complete mental repose, with the mind a perfect blank, for example. The influence of mental effort upon heat production has interested physiologists for many years. In connection with basal metabolism we are concerned more particularly with the effect of moderate mental activity rather than the intense mental effort of a mathematician, for example. But in order to study the effect of mental effort and to secure, theoretically, the greatest effect, the mental work must be sustained and severe. The problem is certainly alluring. But what is mental effort? It is necessary, first, to be sure that we can measure our people without mental effort and then with mental effort. But how can we be sure of sustained mental effort with any given individual? Will the reading of a book of poems insure it? Certainly not. Memorizing a passage? For some persons, yes, for others, no. But we agree that with the average college student there is one time (perhaps the only time in the whole year) when he experiences sustained mental effort and that is during the hours of his mid-year or final examinations. We therefore arranged with the college authorities to have twenty-two students take their examinations, one at a time, inside

TABLE 5

METABOLISM DURING MENTAL WORK
QUANTITIES PER HOUR

	Examination period	Control period
Carbon dioxide	33.42 grams	32.76 grams
Oxygen	27.30 "	25.86 "
Water vapor	39.23 "	37.80 "
Heat	98.80 calories	98.43 calories

Averages of forty-four experiments

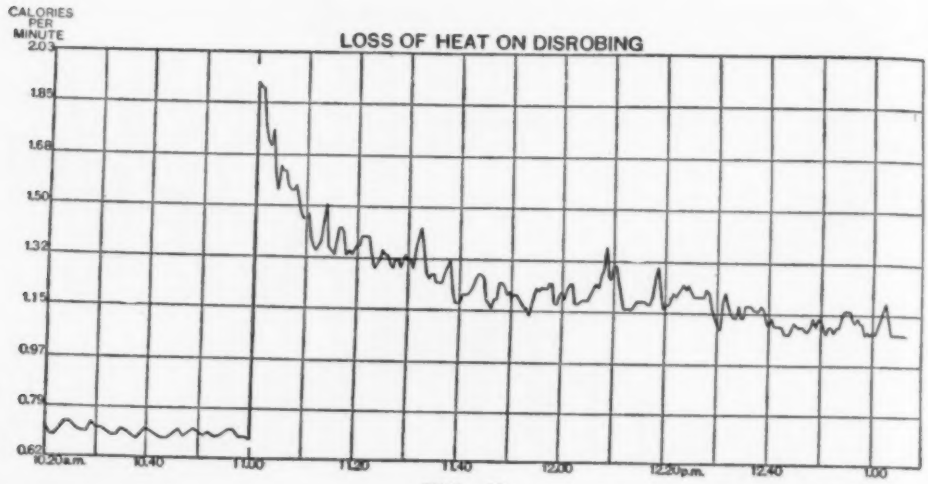


FIG. 18

of a respiration chamber, which was likewise a calorimeter. Subsequently, as a control, each was studied in the calorimeter at a period some time after the examination. To include the mechanical work of writing, the students were told to copy some simple prose which was extremely uninteresting to them. The measurements were not made under basal conditions, but the *only* factor which differed in the two series of experiments was the mental effort. Under such conditions the specific effect of mental effort, if any, should be noted. The measured metabolism, when the men were under severe mental strain, compared with the measured metabolism during the control period showed no significant effect of mental effort. This is very disillusioning to many of us.

What is the effect of psychic unrest, as expressed by mental agitation, distress, anger or unhappiness? To plan experiments definitely along this line is obviously difficult. Incidentally, at the Nutrition Laboratory a few years ago my associate, Dr. T. M. Carpenter, was studying the metabolism of an assistant nearly every consecutive morning, and this assistant had ordinarily shown an unusually uniform heat production. He was well trained, remained very quiet during the measurements, and there was nothing novel in the situation for him. One morning, when Dr. Carpenter thought he was particularly quiet and relaxed, the metabolism was greatly increased. Instead of being satisfied with two or three test periods, as usual, Dr. Carpenter made still more, and the metabolism still remained high. There was no fever, and no other cause for the increase was apparent. Questioning, however, brought out the fact that the evening before the young man had attempted to elope with one of the young ladies of the laboratory and her father had kicked him down three flights of stairs into the street, which resulted in a great deal of physical as well as mental unrest. The next morning he was experiencing the after-effects in the shape of a considerably increased metabolism, which showed even above the seeming muscular exhaustion and somnolence.

These studies on the factors affecting basal metabolism covered a number of years, and during this time the Nutrition Laboratory obtained repeated measurements on four different staff members at

fairly frequent intervals. Hence we now have available evidence regarding the effect of age with one and the same person, unfortunately not during the rapid period of growth from birth to puberty, but at least for the period between twenty-five and sixty years of life, including the more critical period at about forty to forty-five years. From this evidence it is apparent that from about forty years on there is a distinct tendency for a decreased metabolism, both in the measured heat production and in the pulse rate.

With one of the subjects, a woman, the age range studied happened to be between twenty-five and thirty-five years, and during this particular age range it was found that the metabolism in general remained essentially unaltered. Rather frequently, however, when the metabolism was the lowest, it was coincidental with menstrual days, and although this subject, an artist's model, is unusually normal and but little inconvenienced by the menstrual period, it was thought that a slight feeling of malaise might have caused this lower metabolism.

We all have days when we feel below par and days when we feel better than on other days. Is this reflected in the basal metabolism? The periodic experience of normal women with menstruation is usually accompanied by a feeling of malaise, and measurement of the metabolism during the period of this normal, regular function is perhaps one of the simplest methods of studying the effect of feeling below par. We have just completed a series of daily measurements of the metabolism with this same woman over a period of two months, in which it is seen that although this normal function causes her practically no inconvenience, there is a distinct tendency for the metabolism to be slightly lower during the menstrual period.

A common remedy for "that tired feeling" or the sense of being below par is rest and relaxation. It is for this reason that high-school and college students have the Christmas and Easter recesses, and it is for this same reason that practically every one, both the student and the working person, enjoys a vacation during the summer. The habits of life during the summer vacation are decidedly altered. From a sedentary life indoors we change to a life out-of-doors in the sunlight. We indulge in more muscular activity, such as long hikes, swimming and boating, and we eat more fresh vegetables, berries and fruits. How is the metabolism affected by such a change in the living conditions? This effect again has been studied by the Nutrition Laboratory on twenty-two different individuals, both men and women. These subjects were members of the laboratory staff, accustomed to indoor desk and laboratory work, and the occupation prior to the vacation was typically sedentary. The vacation period extended

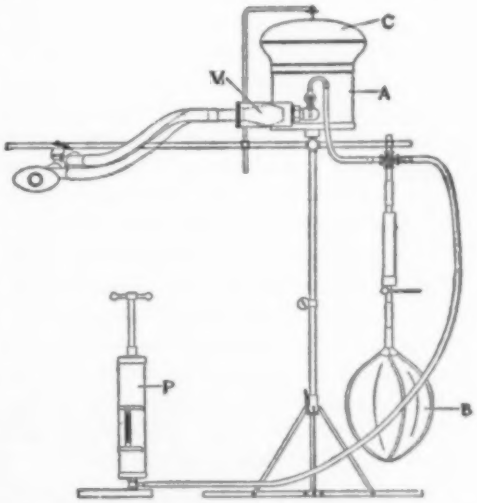


FIG. 19. DIAGRAM OF A FIELD RESPIRATION APPARATUS FOR USE ON EXPEDITIONS IN MEASURING THE OXYGEN CONSUMPTION OF HUMANS.

through the entire month of August, and the metabolism was measured with each subject on at least two different days in July and again on two days in September. The subjects were questioned as to the nature of their vacations and in every instance indicated that the vacation was characterized by greater activity, more outdoor life and change in diet and in environment. Greatly to our surprise, however, it was found that in practically all cases the metabolism of these individuals was exactly the same after the vacation as before. It is astonishing that a procedure which results in such a profound alteration in the subjective feelings, that is, a summer vacation, should not have altered in the slightest the basal metabolism. This is again a strong indication of the fixity of basal metabolism.

In studying the influence of vacation, the effect of a change in season from spring to summer or summer to fall is usually involved. This naturally raises the question as to what is the effect of season. Is the basal metabolism constant throughout the entire year, provided of course there are no marked changes in body weight, or does it alter with the change in seasons? Miss Florence Gustafson, a teacher in the department of physiology at Wellesley College, cooperated with the Nutrition Laboratory in a study of this factor, and measurements were secured on twenty young women students over a period of fifteen consecutive months. The results of the experiments have been assessed only within the last two weeks, and we find that there is a tendency for the metabolism to be lowest in winter, increasing in spring, and remaining unaltered till late fall.

The debt owed to college students by physiologists is further accentuated by the outcome of a series of observations made at Mount Holyoke College, in cooperation with Professor Elizabeth Crofts. A study was being made to determine whether a night's rest in bed should precede basal metabolism measurements, that is, whether the amount of activity involved in arising in the morning, dressing and walking or taking a street car to the hospital or other place where the observations were to be made, affected the basal metabolism appreciably. It was found that the effect of such activity had entirely disappeared after half an hour of complete repose, and it was concluded that it is unnecessary to demand that the subject should be measured in bed, before arising in the morning, thus avoiding the use of a much needed hospital bed. The basal metabolism is therefore but little affected by the extraneous factors which we have thus far considered, such as body position in bed, severe mental work, or the morning activities of arising.

But in spite of the seeming constancy or fixity in basal metabolism, occasionally influencing factors arise that are most surprising. While making this series of observations at Mount Holyoke College, we noted that certain volunteer subjects, Chinese and Japanese, showed a pronouncedly low metabolism. This finding was immediately controlled by measuring a number of other Orientals, both at Mount Holyoke College and, through the cooperation of Professor Grace MacLeod, at Teachers College, New York. It was clearly established that these Oriental college women had a metabolism on the average 10 per cent. lower than the standards for American women. This difference in metabolism is all the more striking, since it can not be explained by differences in climate and diet. These young women had all been for at least one year in America, were living in the same college dormitory and eating the same food as their American college mates, and engaged in the same activities, and seemingly the only foreign factor was that of race. Certain observations in China and

earlier observations in Japan apparently point likewise to a lower metabolism with the Oriental. As a result of this finding at Mount Holyoke College, therefore, the Carnegie Institution has planned to make a fairly extensive study of the metabolism of different races, and considerable progress has already been made along this line.

The attention of anthropologists was immediately challenged by this finding with Oriental women, and the cooperation of a number of collaborators has already been enlisted. For these racial studies a special apparatus has been developed at the Nutrition Laboratory, which is light enough in weight to be readily transportable on expeditions and which permits the measurement of the oxygen consumption with great accuracy. The subject breathes through a mouthpiece connecting with a small can. This can, two thirds filled with soda-lime to remove the carbon dioxide exhaled, is covered with a light-weight rubber bathing cap, which serves as an expansion chamber. As oxygen is removed from the closed system during the respiration of the subject, the bathing cap, which was at first well distended, gradually collapses. Oxygen is introduced by a hand pump of known volume to take the place of the oxygen absorbed. The record of the number of pumpfuls of oxygen introduced and the length of time involved gives a measure of the volume of oxygen absorbed by the subject. Already eight of these appliances have been distributed to members of various expeditions. The following diagram illustrates an experiment made with the apparatus on a subject at the Nutrition Laboratory.

Thus far actual returns have been received from measurements made by Mr. Morris Steggerda, of the Department of Genetics of the Carnegie Institution, on a group of browns and blacks in Jamaica, B. W. I., and measurements made by Dr. G. D. Williams on Maya Indians at Chichen Itzá, Yucatan. The results of these measurements have been computed and the manuscripts are now ready for the printer. With a group of thirty-seven male browns in Jamaica the heat production on the average was, to be sure, 5 per cent. below the predicted heat production for white men in the north. But since a group of thirteen female browns and male blacks had a heat production perfectly comparable to that of white men and women, the evidence of a definite racial factor is obscured. The fact that the hitherto suspected depressing influence of a tropical environment did not appear in general with these browns and blacks argues again against the idea that the body produces heat to keep itself warm.

In the Yucatan series, measurements were made upon certain white members of the expedition, both before they left Boston, while they were in Yucatan and after their return to Boston. Other measurements were likewise obtained on whites who had only recently arrived in Yucatan. These measurements, so far as they go, indicate that the sojourn in Yucatan was without effect upon the metabolism of the whites, thus again emphasizing the absence of effect of a sub-tropical climate. Singularly enough, with the Mayas, all of whom were men, the metabolism on the average was over 5 per cent. *above* the northern standards for white men. Thus not only has the sub-tropical environment *not lowered* the metabolism of these individuals, but some factor, presumably racial, has asserted itself, and we have here a higher metabolism than that of the northern whites. The fact that these men were engaged in archeological excavations may possibly account for part of their increased metabolism, for an athletic person does have a somewhat higher metabolism than a non-athletic person. However, it seems clear that the degree

of muscular exertion involved in their daily occupation could not account altogether for the high level of metabolism. We believe, therefore, that we have with the Mayas a definite racial factor which is wholly comparable to the racial factor noted with Chinese and Japanese, whose metabolism was distinctly low. In view of the fact that the low metabolism of the Orientals has been interpreted by some investigators as indicating racial inferiority, this high metabolism of the Mayas and the contrast between the civilization of the Mayas at the present day and the high degree of civilization of the Orientals speak against interpreting a low metabolism as an index of racial inferiority or a high metabolism as an index of racial superiority.

Problems of racial metabolism are, of course, indissolubly connected with climate, and our recent observations in the Tropics seem to indicate that a warm environment does not lower the basal metabolism. What is the effect of cold? Man ordinarily maintains a uniform temperature for his body by adjusting his clothing to the temperature of the environment, so that changes in the weather do not have a pronounced effect. What would be the effect upon metabolism of exposure of the body to cold? Investigation of this problem gives us an opportunity to learn also what relation heat production has to heat loss. When the body is exposed to cold by removal of the clothing, there is immediately an enormous loss of heat, due to the difference in temperature potential between the skin (which is approximately 33° C.) and the air (which is ordinarily about 15° C.). As a result of this great loss of heat, the skin temperature and, indeed, the tissue temperature is lowered, thus reducing the difference in temperature potential between the skin and the environment. Finally, however, the fall in skin temperature ceases and the loss of heat is adjusted to the prevailing temperature potential.

Recently a calorimeter has been developed at the Nutrition Laboratory, which is sensitive enough to measure the heat loss in periods as short as one minute. A subject was placed inside the calorimeter, nude, but covered with several blankets. The loss of heat under these conditions was first measured for about one hour, and found uniform. By means of cords inside the chamber, the blankets were then suddenly rolled away and the nude body was exposed to the cold air. As can be seen from the curve herewith, there was immediately a pronounced loss of heat. Finally the heat loss reached an approximately constant level, but the loss was still greater than it was before the blankets were removed.

How does the heat *production* compare with heat *loss*, especially when the loss of heat is very great? The heat production, as we now know, is best measured by the oxygen consumption. It has been found that the oxygen consumption or the heat production increases with exposure to cold, as does the heat loss, but not to the degree that one would expect. Thus, experiments were made with the same subject studied in the calorimeter, an artist's model who was well trained to posing without clothing. After lying for fifteen minutes, nude, in a cold room at 11° C. (52° F.), the subject's oxygen consumption was 211 cc. per minute, as seen from this table. During the next forty minutes of continued exposure there was but a small increase (5 per cent.) in the oxygen consumption, al-

TABLE 6

EFFECT OF SHIVERING UPON OXYGEN CONSUMPTION PER MINUTE (SUBJECT LYING, NUDE, AT 9:14 A. M.; ROOM TEMPERATURE, 11° C.)

Time	Oxygen consumption	Remarks
A. M.	cc	
9:30	211	
10:10	221	
10:40	275	Shivering
10:55	286	Shivering

though the room temperature was very cold for a nude person. Indeed, only when the point of shivering, which is in reality a form of muscular work, was reached, was there any considerable rise in metabolism. This indicates that only under extreme conditions and as a last resort is heat produced to keep the body warm, *i.e.*, when there is an unusually great loss of heat to the environment. Under ordinary circumstances, however, heat production is an end product and not the main object of life.

Another indication that heat is not produced primarily to keep the body warm was obtained in experiments which Mrs. Benedict and I have made on the effect of a neutral bath. In basal metabolism measurements it has been the custom to have the "room temperature" presumably somewhere between 15° and 20° C., and to make certain that the subject is comfortably relaxed, neither too warm nor too cold. Little, if any, attention, however, has been given to recording the kind and amount of clothing and bed covering. It has been suggested that if the body were immersed in a neutral water bath at 35° or 36° C. (*i.e.*, at essentially the same temperature as that of the body), the metabolism measured under such conditions would be the true basal, that is, it would be lower than when measured under the ordinary conditions prescribed for basal measurements. Another suggestion has been that the metabolism is at its lowest point *after* the subject has left the bath and has been lying down for some time. These suggestions were tested with several subjects, whose metabolism was measured, first, while they were lying clothed and lightly covered, in a room at 15° C., then while they were immersed in a neutral water bath at 35° C., in a very warm room (30° C.), and subsequently after the bath, when they were again lying down, well covered. The results of two of our experiments are shown in the accompanying table, from which it is seen that there is a slight *increase* in metabolism during the bath

TABLE 7

INFLUENCE OF A NEUTRAL WATER BATH (36° C.) UPON THE OXYGEN CONSUMPTION (CC.) PER MINUTE

Condition	May 13	May 14
Before bath (lying, clothed)	177	168
In the bath (96.8° F.)	188	185
After the bath (lying, well covered)	176	167

and that afterwards the metabolism returns to its initial level. It is, therefore, clear that the neutral water bath does not lower the basal metabolism and that the ordinary room temperature is a satisfactory thermal condition for making basal measurements on the clothed and suitably covered subject.

These neutral bath experiments indicate that heat is not produced to keep the body warm, for the conditions during the bath were such that but little heat could be lost from the body and yet the level of the oxygen consumption or the heat production was not lowered. The problems of heat production are, however, subtle. The muscles, without doubt, produce the most heat when we are up and actively about, but the cells produce a great amount of heat by themselves, and when the body is overheated the chemical action becomes tremendously accelerated, as in fever.

We know that in disease there are great changes in metabolism, even when the individual is lying quietly. In toxic goiter, for example, the basal metabolism is increased 60, 80, or even 100 per cent. and in another thyroid disease, myxedema, it is greatly decreased, 40 or 50 per cent. These changes are now explained by the fact that there is normally discharged from the thyroid gland a substance (thyroxin), a so-called "hormone," which stimulates metabolism. When it is discharged in excess, as in

toxic goiter, the metabolism is increased, and when its discharge is deficient, as in myxedema, the metabolism is decreased. In this latter case, fortunately, it is now known that administration of the pure product will increase the metabolism greatly. The intelligent use of basal metabolism measurements has been of considerable aid to clinicians in handling these two diseases. In fact, basal metabolism measurements are practically a prerequisite to establish the clinical picture for all patients with either toxic goiter or myxedema. Hundreds of basal metabolism measurements are made each week in the United States alone on patients of this type.

Fortunately the majority of individuals are not afflicted with disease. A more common affliction is overweight. During youth and the period of rapid growth, indeed up to thirty years of age, statistics show clearly that overweight is a distinct asset towards longevity. Beyond thirty years it becomes a liability of no mean significance. But the keen appetite for food so fortunately provided for us by nature during the period of youth and activity has established such a firm habit upon us that the tendency is to keep up the food intake, notwithstanding the fact that with advancing age the physical activities are lessened and there is therefore an ever-decreasing heat output. The inevitable result is increase in weight, which begins with plumpness, passes through embonpoint and finally ends up in obesity, which should always be called *fatness*. The chief cause of obesity is overeating. Contributory factors may be errors of diet, errors in exercise and certain pathological conditions. But when you eat a little more than you burn up, it must be deposited in the body. The insidious way in which a small daily excess may contribute to build up fat is illustrated by the fact that if but one small pat of butter, corresponding to ten grams, is eaten *in excess* of one's needs each day for a year, it will cause an increase in weight of eight pounds. Two extra lumps of sugar eaten each day throughout a year, or the equivalent amount of candy (a nougatine, for example), would also cause the same increase in weight.

Basal metabolism measurements have been of incalculable service in studying the various types of obesity, and when dietetic restrictions are to be supplemented by medication, such as the administration of thyroid to whip up the internal metabolism, such measurements are imperative. Fortunately for most people intelligent dietetic control will permit of weight reduction. But as the increase in weight is usually not sudden, but comes on with insidious surety during two, three or more years, the removal of weight must likewise not be sudden but slow. The effect of rapid loss of weight is of course most strikingly shown with the fasting individual. The man who fasted thirty-one days at the Nutrition Laboratory lost twenty-nine pounds and he looked it. (See Fig. 11a and 11b, page 14). For the ordinary person rapid reduction is a distinctly dangerous procedure. A mild reduction in food intake, even no more than simply ruling out visible fats, will accomplish a great deal. But it must not be forgotten that obesity is a condition which really demands the fullest cooperation with a skilful physician. Frequently the physician will employ basal metabolism measurements as an index of whether the patient is tolerating the weight reduction.

Exactly as basal metabolism measurements are used by the physician as a general index of the intensity of vital processes with the overworking organism of toxic goiter and with the underworking organism of myxedema, and exactly as these measurements are used to help him in his control and treatment of obesity (along with numerous other

pathological cases), so basal metabolism measurements are becoming more and more to be looked upon as the best index of the vital activity of any individual. To a certain extent the basal metabolism may be considered as the "indicator card" of the human engine, showing its general efficiency, not, to be sure, for muscular work, as in the case of the mechanical engine, but at least for the overhead maintenance of the well-functioning body prior to putting on the superimposed tasks of daily life, whether these be mental or physical. For physical capacity further testing of course is necessary, particularly in severe muscular work. But even here metabolism measurements superimposed upon basal metabolism measurements are giving the best picture of the capacity of the body for physical exercise, the relationship between external muscular work performed and the actual energy required to perform it and the efficiency of the human body as a machine. These represent special uses of metabolism measurements and are always interpreted in terms of the basal metabolism. For every healthy individual, therefore, there is a normal, remarkably fixed basal metabolism which, as we have seen, does not undergo changes even with considerable superimposition of other factors. When the basal metabolism profoundly alters, it is usually due either to disease or to some profound change in the general makeup. This change may frequently be a betterment of the organism, or not infrequently it represents a stage of being below par. In this sense, therefore, measurement of the basal metabolism is a splendid index of the level of vital activity, and it is highly probable that in the next decade we will find that basal metabolism measurements will be included in the annual physiological and medical survey which doubtless all of us will consider essential.

THE FUN OF BEING A SCIENTIST

By Dr. J. O. PERRINE
AMERICAN TELEPHONE AND TELEGRAPH COMPANY

LEVITY and laughter are recognized as attributes of Will Rogersian jesters, but popular opinion gives them no place in the life of a research scientist. Fun and profundity have always been placed in the same class with oil and water. They are never mixed. Pep and personality are the *sine qua non* of wild-cat stock salesmen, but absent-mindedness, self-effacement and a fish-tail handshake are accepted by the world in general as the inevitable concomitants of brains as exemplified by professors. They and other savants have ever been pictured and portrayed as myopic and sadly in need of tonsorial attention. War heroes, motion picture stars and fleet halfbacks are pointed to with pride, to borrow the politician's lingo, while a life devoted to biology or mathematics, acknowledged to be commendable and altruistic, is not accepted as a model for flaming youth. There are many who believe that Captain Kidd and Robin Hood are the only ones who really ever lived. Magic carpets and Aladdin's lamps are pure fiction pulled out of fairy tale books by Douglas Fairbanks.

It is granted that scientists and professors do not generally display their enthusiasm and abandon to joy like the Yale students playing goal posts on Soldier's Field. The former have their fun on a Saturday afternoon working in a laboratory, perhaps malodorous and dark, while the latter have their particular brand of fun standing in the rain and getting sore throats yelling, "Block that kick! Block that kick!" If the devotees of Ike Walton see no fun in looking through a microscope or scrutinizing test tubes or listening to radio signals coming from half way round the world, nothing is proved. It all depends on what kind of fun one likes best. The scientist has his kind and feels no need of pharisaic sympathy or condescending condolences.

The only justification for setting down these musings is that having seen something of fun inside and outside scientific circles, there is a possibility that the recital of a few instances inside the circle will afford a little fun and the semblance of a thrill to those outside. Not ever having made a hole in 1, a 3 on a par 4 once caused the writer to unleash a yell. He has never made a great discovery in science, but he has done some work recognized to be worthy of publication. He has made a touchdown in the last minute of play after catching a forward pass, and from a lofty tier in the La Scala at Milan, heartily enjoyed the antics of Ping, Pang, Pong, singing in Puccini's Turandot. It has been his privilege to visit practically all the great physical laboratories of America and a goodly portion in Europe, to know famous scientists at home and abroad and to see and feel some of the enthusiasm and fun which charge the atmosphere at Leiden, Cambridge, Cornell and Johns Hopkins.

EXHIBIT A

The antagonism to Galileo and his hated telescope became very strong in his day. The clergy began to denounce him and his methods. One ecclesiastical opponent became known as a punster by preaching a sermon from the text, "Ye men of Galilee, why stand ye gazing up into Heaven?" Galileo had turned his telescope toward Jupiter and saw its satellites. On the moon he had discov-

ered mountains and craters. In 1610, Galileo wrote to Kepler as follows:

> Oh, my dear Kepler, how I wish that we could have one hearty laugh together! Here, at Padua, is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my glass, which he pertinaciously refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly! And to hear the professor of philosophy at Pisa labouring before the Grand Duke with logical arguments, as if with magical incantations to charm the new planets out of the sky.

Shades of Sir Andrew Aguecheek and Sir Tobey Belch in riotous laughter in the tavern of "Twelfth Night."

EXHIBIT B

Galileo was born on the day of Michel Angelo's death. One might fancy that this signified the passing of the scepter from art to science, for science was destined to receive a great impetus from this remarkable man.

The young lady strolling through the garden on a clear night and who to her escort expressed admiration of the astronomer's ability to know the names of the stars envisioned the deciphering of millions of names. As a matter of fact, a person can see with the unaided eye only about three thousand stars. All persons over the entire face of the earth can see less than ten thousand stars. Galileo made a simple telescope, pointed it toward the heavens and revolutionized human thought because he multiplied the number of visible stars one hundred times. With the aid of long, photographic exposures and modern developments of the telescope, a billion of stars have been revealed. How many stars are still behind the veil, of course, is not known, but there are many, no doubt. Have the astronomers any fun? They sit up until three o'clock in the morning to see a star in the heavens, not in a theater or cabaret. Do they have to see a Ruthian homer with the bases full to get a thrill?

EXHIBIT C

The aurora borealis is a most gorgeous spectacle. Streamers of light and bands of color flash across the sky and quiver in the zenith. Man has simulated the aurora borealis, sending a current of electricity through a long glass tube from which the air has been pumped out. If one tries to send a current of electricity with the tube full of air, nothing much happens, but after the vacuum pump has done its work for a little while, streaks of purplish light become visible. Then areas of rose-colored tints, then striae shift from one end of the tube to the other. With the vacuum pump still working, black areas develop, and later brilliant blues and greens delight the eye. In 1893, Sir J. J. Thomson wrote the following:

> The phenomena attending the electric discharge through gases are so beautiful and varied that they have attracted the attention of numerous observers. The attention given to these phenomena is not, however, due so much to the beauty of the experiments as to the widespread conviction that there is perhaps no other branch of physics which affords us so promising an opportunity of penetrating the secret of electricity; for while the passage of this agent through a metal or an electrolytic is invisible, that through a gas is accompanied by the most brilliantly luminous effects, which in many cases are so much influenced by changes in the conditions of the discharge as to give us many opportunities of testing any view we may take of the nature of electricity, of the electric discharge, and of the relation between electricity and matter.

One of the phenomena of discharge which was receiving much attention at the time this passage was written was that of the "cathode rays." Years before it had been found that the discharge in a very highly exhausted tube is accompanied by the appearance of these rays emanating from the negative terminal. They cause a brilliant fluorescence of the glass wall where they fall upon it.

Roentgen in 1896, while investigating this brilliant fluorescence, made a mar-

velous discovery. He noticed that photographic plates, amply protected from ordinary light, became blackened when in the vicinity of such a tube. Continuing his investigations, he found that photographic plates would be blackened even when blocks of wood and other opaque objects were between the plate and the electrical discharged tube. One day, a key was placed between the covers of a thick book and interposed between a photographic plate and his tube. Imagine his state of mind when he found on the photographic plate a picture, more accurately stated, a shadow of the key. Among the graduate students studying under this great man the report spread rapidly that the "old man" had discovered a new kind of light, light that will pass through opaque subjects. Not much is known of this light, this new kind of rays, and so they are called X-rays.

As predicted by Sir J. J. Thomson, these X-rays have been a most valuable tool in finding out the relation between electricity and matter. Hundreds of investigators have been at the job. They have worked long hours in tiny rooms of laboratories throughout the world, in dark rooms they have developed photographic plates and anxiously watched the plate reveal its spots of black as the liquid in the developing pan played over its surface. The applications of X-rays are household information to-day. What fun and thrills the scientists had before the days when the world at large knew about them. Who scoffed at Aladdin's lamp and magic carpets?

EXHIBIT D

From those in whom the wells of humor have not been dried up by the dust of things, Junior's experiment in scuffing his feet on the rug, and later pulling a tiny electric spark from grandpa's ear, will usually extract a laugh. On a cold winter morning, a young lady whose golden tresses are unmanageable on account of the electrified conditions imparted to them by a rubber comb, is at once interested and may even get some fun out of her temporarily acquired bristling bob. In both of these circumstances, the boy and girl can be regarded as an electrical instrument known as the electroscope charged to 20,000 or 30,000 volts. If on them a strong spotlight is played, they lose their electrical charge. The bristling tresses now stay where they are put and grandpa enjoys his snooze unmolested. The mere fact that light, particularly the blue portion of the spotlight, falls upon these electroscopes brings about their discharge. This phenomenon is known among the scientists as the photoelectric effect. If the light is strong the discharge is rapid. If the light is weak the discharge is slow. Heinrich Hertz, of whom one hears considerable these days of radio, first discovered this phenomenon in 1878. It is quite a common phenomenon, particularly apparent in metals like zinc and sodium, one of the elements in common salt. To definitely prove for the first time that light, a mere beam of light, an intangible wand, could be as potent in discharging an electrified body as actual contact with a metal rod, must have provided genuine joy to this young scientist living in Bonn, Germany, the home of Beethoven. Hertz made an epochal discovery, that of a relation between light and electricity. To-day, this discovery is one of the fundamentals involved in the transmission of pictures over wires and also that most recent achievement, television.

EXHIBIT E

Consider further experiments with electroscopes, the work of man's fingers. A scientist's electroscope consists of two strips of gold leaf suspended from a metal rod and put through the sulphur

stopper of a glass bottle. When the expert maker of signs uses gold leaf to place letters on the glass windows of a candy shop, he usually gets an audience because of his dexterity and also because the thin, flimsy sheets of gold leaf are interesting in themselves. Now when this electroscope is touched by the rubber comb which created the bristling bob, the gold leaves diverge. If a tiny speck of radium, that most interesting element discovered by the Curies, is in the vicinity of the electroscope, even a hundred feet or more away with brick and wooden walls intervening, the gold leaves collapse. If you are near the radium, the collapse is fast. If there is no effect, you have no radium. What a game! As much fun as children playing "I spy" with their accompanying shouts of "You're getting hot," "You're getting cold."

Now, in a certain hospital the piece of radium used in medical treatment was carelessly lost. A stupid attendant had thrown it away. Consternation reigned. A potent and remedial agent, scarcer than the proverbial hen's teeth and costing ten thousand dollars, was gone. Then some one suggested, "Let's call a physicist." Yes, he thought he could find it. With an electroscope tucked under his arm and a rubber rod to give it a charge now and then, the game of hide and seek began. In the ash pile, in the waste-paper room, he set up his electroscope and watched its diverged leaves through a telescope. The "scent" was finally picked up. The diverged leaves began to fall very slowly. He moved to a new location outside the hospital. The gold leaves were motionless. He went in exactly the opposite direction. The gold leaves collapsed faster than before. The general direction had become established. (The hounds howl and pull on their leash!) The lost treasure was sure to be found, but there were no secret maps to give its location. The electroscope was moved. The leaves collapsed still faster. Finally the piece of radium was found three blocks away along a river bank in a junk pile. Here was a real adventure. Can Sherlock Holmes equal it? Who mentioned Captain Kidd and Treasure Island?

Exhibit F

Consider the case of Ross, who wrote the following from India after his long struggle to prove that the mosquito transmitted malaria:

> But now, in order to ensure at least definite negative results, redoubled care was taken; almost every cell was examined, even the integument and the legs were not neglected; the evacuations of the insects found in bottles, and the contents of the intestine were scrupulously searched; at the end of the first examination staining reagents were often run through the preparation and it was searched again with care. The work, which was continued from 8 A. M. to 3 or 4 P. M., with a short interval for breakfast, was most exhausting and so blinding that I could scarcely see afterwards, and the difficulty was increased by the fact that my microscope was almost worn out, the screws being rusted with sweat from my hands and forehead, and my only remaining eyepiece being cracked, while swarms of flies persecuted me at their pleasure as I sat with both hands engaged at the instrument. Fortunately my invaluable oil-immersion object glass remained good.
>
> Toward the middle of August I had exhaustively searched numerous grey mosquitoes, and a few brindled ones. The results were absolutely negative; the insects contained nothing whatever. . . . On August 20 I had two remaining insects, both living. Both had been fed on the 16th instant. I had much work to do with other mosquitoes, and was not able to attend to these until late in the afternoon, when my sight had become very fatigued. The seventh dappled-winged mosquito was then successively dissected. Every cell was searched and to my intense disappointment nothing whatever was found, until I came to the insect's stomach. Here, however, just as I was about to abandon the examination, I saw a very delicate circular cell, apparently lying amongst the ordinary cells of the organ, and scarcely distinguishable from them. Almost instinctively I felt that here was something new. On looking further,

another and another and another similar object presented itself. I now focused the lens carefully on one of these, and found that it contained a few minute granules of some black substance, exactly like the pigment of the parasite of malaria. I counted altogether twelve of these cells in the insect, but was so tired with work, and had been so often disappointed before, that I did not at the moment recognize the value of the observation. After mounting the specimen I went home and slept for nearly an hour. On waking, my first thought was that the problem was solved, and so it was.

Is this adventure? Is this romance?

Exhibit G

A professor of forestry recently had an enjoyable experience. Years ago this professor had a lot of fun, according to his own statement, determining what relation the growth rings in tree trunks and the general shape of trees had to wet and dry ground and to rain and drought. Recently the United States sued some lumbermen in Arkansas for cutting timber that did not belong to them. In court the culprits claimed that they had acquired rights by the purchase of claims from early settlers who had lived on the shore of a lake that had dried up about 1840, in which area the cut timber had been. The whole case hinged on whether there had been a lake or not. Well, this professor went down and proved scientifically and conclusively, using cypress trees and old stumps of trees as evidence that there had not been any lake present for at least 150 years. The government got its money all right and, incidentally, just to make the joke complete, the professor got a substantial fee. If there is any man on earth who had a good time, it was this research forester.

Exhibit H

Joseph Henry is one of America's really great figures in science. While professor at Princeton, about 1830, he made important contributions to electromagnetism. To-day, electric sparks are provided for gas ignition in thousands of internal combustion engines by a method discovered by Henry. Two or three dry batteries connected to a coil of about one hundred turns, wrapped around an iron core, thence to the contact inside the cylinder opening and closing does the trick.

In 1837, Henry was in Great Britain and became personally acquainted with England's great physicists. He loved to spend many hours in the company of Michael Faraday, the master experimenter of all time. One day at King's College, Cambridge, Faraday, Wheatstone and Henry tried to get an electric spark from a tiny battery. The Englishman attempted it and failed. Henry, knowing the effect of long wire wrapped around a piece of soft iron, succeeded. It is recorded that Faraday became as wild as a boy and jumping up and down, shouted, "Hooray for the Yankee experiment."

For a scientist, there is no joy like that of working in his chosen field. Oliver Wendell Holmes said, "What have we to do with time but to fill it with labor, to work, to know, to discover and create."

To this the scientist, like the artist, the manufacturer, the business man, the poet, the architect, th enovelist and the clergyman subscribe most heartily. Furthermore, for them it is great fun.

THE MOST INTERESTING WILD ANIMAL IN AMERICA

By EDWARD R. WARREN

LATELY ROOSEVELT GAME NATURALIST, ROOSEVELT WILD LIFE FOREST EXPERIMENT STATION, SYRACUSE, N. Y.

THE most interesting animal in America—at least the beaver is so regarded by many people acquainted with our wild life. And when we take into consideration his intelligent ways, his admirable engineering skill and his quiet, persistent industry, this undoubtedly is true. The beaver was so important a feature in the early history of our country because of its abundance and its highly prized fur that the memory still persists in common geographic names throughout the north; and it has even left its mark in our daily speech, as in the expression, "to work like a beaver." Recently the public has been taking a renewed interest in this fur-bearer, so that we are restocking our wild parks and forests where it has long been exterminated by too intensive trapping. In the Adirondacks, for instance, any one may see the beaver and study his remarkable works along the numberless forest streams of his ancient haunts. In states where the animal was once almost exterminated, strict protection has brought back the beaver population, perhaps increased it over its original numbers.

If you do not know the beaver, imagine a huge, heavily built muskrat, half a foot more than a yard long, with a wide, flat, scaly tail, and of much the same brown color and shape as the muskrat, and you have a fair likeness of a beaver. The hind feet are broad, and webbed like the foot of a goose, with curiously specialized nails on each of the inner toes. These nails are used in combing the fur, as was confirmed by watching captive beavers. The forepaws are smaller, not webbed, and very useful as hands, but are not used in swimming.

The large incisor teeth in each jaw are the tools with which the beaver does his tree cutting. Of an orange color in front, they consist of a hard layer of enamel backed by a softer one of dentine, which is much the thicker, and wears away so much faster that there is always a sharp chisel-edge on the tooth. The teeth are long and rootless, curving far back into the skull and lower jaw, and as they wear away from use they are continually renewed by growth from behind.

It is not its appearance, however, but the things which it does that make the beaver so interesting. The animal is an engineer and builder. It constructs dams, canals and houses, and often does these things in such a manner that it has been credited with almost human intelligence.

When beavers start a new colony on a stream the first thing they do is to build a dam and make a pond, unless the stream happens to be so deep that this is not necessary, or it is so turbulent that dam building is impossible. The first step is to cut brush, usually willow or alder, and lay it on the bottom, butt ends upstream, weighting it down with gravel, mud and stones dug from the bottom above the dam. This is followed by more brush, and then more mud, and so on, until the dam is built to the surface. While, so far as I have had opportunity to observe, the foundation of the dam is usually, if not always,

A BEAVER MEADOW OVERGROWN WITH WILLOWS
PARK COUNTY, COLORADO. E. R. WARREN, PHOTO.

composed of branches laid longitudinally with the current, it would appear that as the structure rises, sticks may also be laid transversely, as the examination of the broken ends of dams seems to show. When the dam is well along toward completion the sticks from which the bark has been eaten are brought to it and deposited in all sorts of positions. Digging material from the bottom leaves a trench of varying width and depth above the dam. At first the water escapes through the numerous interstices, but the stream brings down silt which quickly stops the leaks in the dam. Soon the structure is tight and the pond begins to take form above it. Probably most dams when first built are short and straight, but they are continually repaired and lengthened, and in their final form may be quite crooked. As the water rises in the pond it tends to escape around the ends of the dam, which is extended to stop this, very likely turning up or down stream, as the topography may decide. Then the water rises higher in the pond, and the dam has to be raised. More water goes around the ends and more extension is necessary. It is a continuous process as long as the pond is occupied. Beavers are often credited with building their dams with an upstream curve, the better to withstand the force of the current. True, one often sees dams so constructed, but just as frequently finds them with a downstream curve. The whole thing is a matter of chance, I think, usually the result of extending the ends from time to time. Dams are of all lengths, from tiny ones a foot or so long, up to the one mentioned by Enos Mills, over three thousand feet long; and in height up to fourteen feet, though this is very unusual. The height

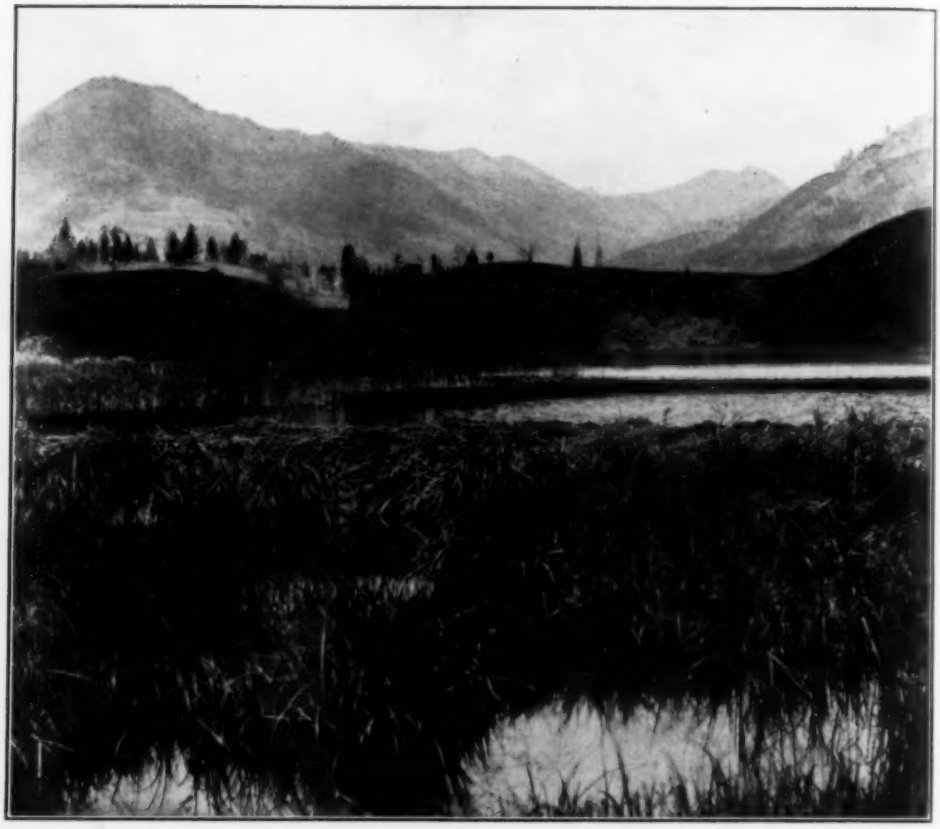
of the face of a dam rarely exceeds five feet, and most are considerably lower.

The size of a pond made by a dam depends chiefly on the gradient of the stream. On one with much fall the pond will be short, not infrequently much shorter than the length of the dam. On the other hand, a dam on a stream with a slight fall may back the water up for a long distance. An instance is given of a dam in the Adirondacks, seventy-five feet long, which resulted in a "beaver flow" a mile long.

Often there is a succession of dams and ponds along a stream. These serve various useful purposes: residence, water transportation and travel, and protection of the dams themselves. Water in the lower ponds backed against the dams above protects and strengthens them so that they more easily withstand sudden or unusual strains caused by floods or floating ice. The upper ponds of a series act as reservoirs to hold back flood water and prevent it from damaging the ponds below. Incidentally this is one of the benefits the beaver confers on mankind, the storage of water in the ponds, and the prevention, to some extent at least, of floods. There are instances where beaver ponds made it possible to range cattle where it could not be done before the beavers settled on the stream, there not being sufficient water for the live-stock until they came and conserved it. In certain places beavers have also made more water available for irrigation, and crops have been saved by its use.

When a beaver pond is abandoned by its owners it soon begins to fill with silt and other material brought down by the stream. Very likely this filling has begun before abandonment, may even have been one of its causes. As the water

A BEAVER HOUSE
GUNNISON COUNTY, COLORADO. E. R. WARREN, PHOTO.



A BEAVER DAM AND POND
GUNNISON COUNTY, COLORADO. E. R. WARREN, PHOTO.

drains away, grass and other vegetation begin growing, and after a while instead of wet swampy ground we have a quite dry meadow covered with grass and it may finally become covered with willow bushes. This result may be attained in a very few years, or it may require many. Beaver meadows have furnished hay for pioneers in many places and have doubtless been among the first lands to be taken in the early days of our country. The level ground, comparative freedom from brush or timber and fertile soil rendered them desirable when the land had to be reclaimed from a state of nature by hard work.

A sort of romantic interest seems to be attached to the beaver's house or lodge, the typical form of which, standing in the pond with water all about it, always attracts attention. There are other forms of the lodge which are not so conspicuous. These are built on or against the bank, and are called "bank lodges." Like the dam, the house is built of sticks and mud. When away from the shore or bank it usually has a foundation of some sort, either a small island or a high spot on the pond bottom; or the builders dig mud from the bottom and pile it on the chosen site. In doing this last they at the same time make deeper water about their home. On this foundation mud and brush are piled, somewhat as in building a dam, though the sticks are laid crossing in all directions. As the

structure rises above the surface little or no mud is placed on the central portion. When the house is completed the interstices between the sticks of this part give ventilation.

After the lodge is raised to the required height the builders burrow up into it from deep enough below the surface to prevent the entrance being closed by freezing. The sticks are cut away as reached. When the entrance attains a point within the structure a few inches above the water level the chamber or living room is made by a continuation of the burrowing, the interfering sticks being cut away and carried out. The room is twelve to eighteen inches high when completed, and of varying horizontal dimensions. Very large houses may have several unconnected rooms, each with its separate entrance or entrances. There may be only one or two entrances to a house and I have found as many as ten. I have seen a lodge only six feet in diameter, and another 33½ by 39 feet, the largest of which I have any record, and there are all sizes between. The outside of the lodge is often plastered with mud, especially at the advent of cold weather, and good-sized logs and poles are frequently placed on it. I saw a railroad tie lying against the side of one house, and a water-worn piece of two by four on top of another.

Many beavers never build lodges, but live in burrows in the banks, and as a matter of fact the lodge-dwelling beavers are never without burrows to which they can retreat when necessary, if pressed by enemies or the lodge is destroyed. Burrows are anywhere from ten to thirty feet or more long, having their mouths below the surface of the water, but soon rising above water level, and having a room or chamber at or near the end. Some bank lodges appear to be widened parts of burrows roofed over. Others placed against a bank are probably built in much the same manner as those which are out in the pond. I have also found small chambers or rooms in the bank, just below the surface of the ground, roofed with sticks and mud, and large enough for not more than two beavers. These were entered by holes from the water.

The third of the beaver's works is the canal, often a real engineering achievement, more so than either of the others. Canals are usually made to transport food, and may be anywhere from a few feet to more than seven hundred feet long, as in the case of one reported from Montana. They vary from ten inches to two feet deep, and one to four feet wide. They are made by digging the earth along the desired course and piling it on the bank alongside, often doing a very neat job. Frequently a canal has two, or even three levels, the first or lowest deriving the water supply from the pond, the upper level from some other source, such as springs or from swampy ground through which it has been built, or even from another stream. A dam separates the two levels, and the transported material is dragged down over this to the level below.

Beavers depend mostly on the bark of trees for their food, using the inner or cambium layer next the wood by preference, though one finds logs stripped of their bark with none of the outer bark lying about, so that some use must have been made of it. Deciduous trees of almost any available kind, but preferably aspen, are their mainstay, though under certain conditions the bark of conifers is utilized, and here the rough, dry outer bark is sure to be rejected. In summer various shrubs, herbaceous plants and grass are eaten.

To obtain the bark of trees the latter must first be felled, and this is done with the large incisor teeth. Beavers do not cause the trees to fall in any desired direction, though some have claimed that they do, but cut them in the most con-

A COTTONWOOD TREE CUT DOWN BY BEAVER
E. R. WARREN, PHOTO.

venient fashion, and let them fall as they may, usually in the direction in which they happen to lean. Sometimes this woodcutter chips evenly clear round the trunk, and sometimes he cuts all the way through from one side, even with good-sized trees. In cutting, the beaver takes a bite at the upper and lower sides of the notch, and then removes the chip by a sidewise cut and prying action. I have seen chips several inches long taken from large aspens. When felled the branches are cut off and carried away, and the trunk, if not too large, is cut into lengths suitable for transportation, although large logs may be stripped of their bark and left where they fell. As winter approaches the beaver lays in a store of food in the shape of branches and logs, placed in the water convenient to its house or burrow. This store is piled on the bottom, the green wood soon becoming water-logged and remaining in place. Large amounts of this material are sometimes accumulated by a beaver colony. In winter the animals swim under the ice to the foodpile, select a stick and return with it to their home, where they eat the bark, afterward discarding the stick. These discarded sticks often find their way to the dam.

The sticks are carried by taking hold with the teeth near one end and either dragging them alongside or throwing them over the shoulder. Large logs may be rolled to the water by pushing them with the forepaws.

Trees for housebuilding and dams are cut in the same manner as for food, and are often stripped of their bark before being placed in the structure, so that no food is wasted. A tree over three feet in diameter has been known to have been felled by beavers.

Beavers bear their young probably in April or May, four or five being the

A DAM WHICH HAD BEEN CUT THROUGH BY THE STREAM

IT SHOWS THE MIXED ARRANGEMENT OF THE STICKS IN A COMPLETED DAM. GUNNISON COUNTY, COLO. E. R. WARREN, PHOTO.

average number. The young are born fully furred and with their eyes open. The young stay with their parents until more than a year old, so that the normal beaver family consists of two adults, the yearlings, and the young of the season or "kits" as they are called.

The average number in such a family is difficult to state. One family which came under my observation consisted of eight, there being three of each of the two ages of young. This may not be far from the average, as enemies doubtless take toll from both old and young. The youngsters are playful, especially in the water. In the lodge they have a whimpering note, somewhat like a young puppy, without any whining tone.

It goes without saying that the beaver is an expert swimmer, using the broadly webbed hind feet as propellers, and occasionally sculling with the tail, which is also used as a rudder, which is perhaps its usual function in the water. The animal is able to swim under water several minutes at a time. It is an easy diver, and can slip into the water or submerge very quietly if it so desires, or it may alarm the whole neighborhood with a resounding whack of its tail as it goes down. A beaver has been seen to swim in daytime for an hour or more, frequently diving with a slap of its tail apparently in sport, though this tail slapping is commonly supposed to be a danger signal.

Naturally, the beaver has its enemies. Man, of course, is the worst. Coyotes, wolves, cougars, lynxes, bobcats, bears, all like a taste of beaver meat when they can get it. Usually the victims are surprised on land, but occasionally, no doubt, one is taken when in shallow water.

Ever since the American continent was settled the beaver has been trapped for its fur, at first mainly for the purpose of obtaining material for making hats. Even now, the formal "stovepipe" is often referred to as a beaver. The manufacture of hatter's silk, and the substitution of the fur of the South

A BEAVER ON THE DAM

TAKEN IN THE DAYTIME IN THE YELLOWSTONE NATIONAL PARK. PHOTO BY E. R. WARREN, PUBLISHED BY COURTESY OF THE ROOSEVELT WILD LIFE FOREST EXPERIMENT STATION.

A COTTONWOOD TREE PARTLY CUT BY BEAVER

THE RULE LYING ON THE STUMP IS TWO FEET LONG. TRINCHERA ESTATE, COLO. E. R. WARREN, PHOTO.

American nutria for the same purpose, put an end to this use. This perhaps gave the animal a short respite from the trappers. But the fur is of too fine a quality not to be utilized, and there has always been a demand for it. At the present day it brings a high price in the market. The persecution by trappers resulted in the beaver's extermination over a great part of its range, and probably nowhere, except possibly in a few favored localities under strict protection, could it be found in anything like its former abundance. The Yellowstone National Park is a splendid example of the result of local protection. Here the animals are flourishing, increasing greatly in numbers, and often to be seen swimming in their ponds or going ashore after food, quite indifferent to the silent spectators who may be standing close by watching every movement with the greatest interest. It was my belief during the two summers I spent studying the beavers near Camp Roosevelt in the park that these were the animals of most interest to the tourist. They all wanted to know about them and to see them. It

was here that I made a somewhat extended study of the animal and its works, the results of which are contained in the Roosevelt Wild Life Annals, "The Beaver in the Yellowstone National Park."[1]

Wherever protected beavers increase rapidly. Sometimes too rapidly, one might think. Once exterminated in the Adirondacks, a few from Canada and the Yellowstone Park were liberated there some twenty years ago. They are now numbered by thousands, and it is a question whether their numbers should not be reduced locally to prevent further damage to valued trees or where too much woodland is being killed by flooding. Such control should be done carefully and under competent supervision. Unrestricted trapping would soon reduce the beaver population to the vanishing point; but, on the other hand, under complete protection they may become so numerous as to be their own worst enemy, through depletion of the available food supply. This is something which seems quite possible in the Yellowstone. A reasonable number of beaver should be permanently maintained in such wilderness regions as the Adirondack for the education of the large numbers of campers and visitors who are sincerely interested in all forms of wild life, as well as for the legitimate taking of valuable fur from time to time, according to conditions.

During the past few years attempts have been made at "Beaver Farming," raising beavers in confinement for commercial purposes. The pioneers in this business will probably make their profits from animals sold for breeding and stocking rather than from the fur marketed. Because of the aquatic habits of the animal and the nature of its food the securing of suitable places for such enterprises may be difficult, and it will be some time before many pelts taken from captive beavers come on the market. At the same time the attempts to raise beavers in captivity will no doubt give us much information as to their breeding habits and the care of the young; indeed, they have already done so.

[1] See also "The Beaver: Its Work and Its Ways," The Williams and Wilkins Company, Baltimore.

A VISIT TO THE MUD-VOLCANOES OF TURBACO, COLOMBIA[1]

By ALBERT C. SMITH
LEVERETT, MASSACHUSETTS

Of all the features of lowland Colombia which hold interest for the scientist, none is more deserving of a visit than the mud-volcanoes of Turbaco. Yet this unusual phenomenon has seldom been witnessed by others than natives of the region. Alexander Humboldt, one of the first scientists to realize the potentialities of exploration in tropical America, visited the volcanoes, and through his pen alone have we a description of them.

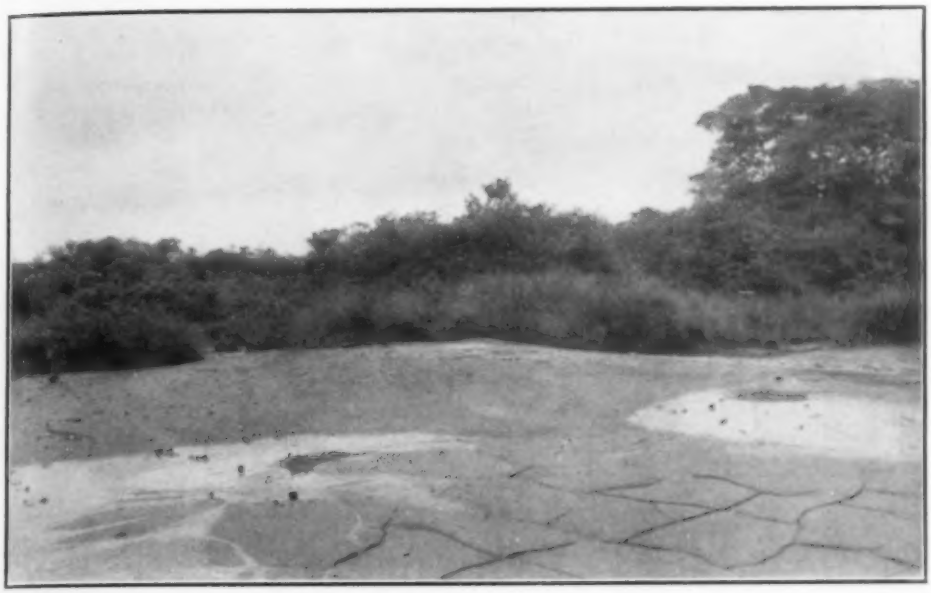
[1] A visit made in November, 1926, by the Killip-Smith Expedition to Colombia, under the auspices of the Smithsonian Institution, the New York Botanical Garden, Gray Herbarium, and the Arnold Arboretum. The photographs are by Mr. Ellsworth P. Killip.

It was the good fortune of a botanical expedition which recently visited Colombia to spend some time at Turbaco, a village near which the mud-volcanoes are situated. Although our primary objective was to collect the plants of the neighborhood, we welcomed the opportunity to visit a scene which, perhaps, no foreigner had witnessed since Humboldt traversed the region. We also looked forward to enriching our botanical treasures, since plants from the territory near the volcanoes are known only from Humboldt's collections.

So we set out from the town of Turbaco, which lies among beautiful roll-

A GENERAL VIEW OF THE VOLCANO FIELD

It can be seen that the slope of the cones is very gradual. Down the sides of some of them the liquid mud is flowing, having been forced from the craters by the rising gases.



A CLOSER VIEW OF TWO CRATERS

THE ONE ON THE LEFT IS NOT ELEVATED AT ALL FROM THE SURFACE OF THE FIELD, BUT STILL IT FORCES OUT MUD. IN THE FOREGROUND THE MUD HAS HARDENED AND CAKED. IN MANY PLACES THE SURFACE IS YIELDING, AND AS DANGEROUS AS QUICKSAND.

ing hills a few miles from the north coast of Colombia. Of all the villages which Humboldt visited in South America, none has he eulogized as Turbaco, praising its climate, its beauty and the charm and kindness of the inhabitants. Continuing, he describes his trip to the volcanoes:

The Indians of Turbaco, who accompanied us on our herbalizations, often spoke to us of a marshy country, situate amongst a forest of palm trees, and called by the Creoles the little volcanoes, *los Volcancitos*. They related that, according to a tradition still existing among them, this spot had formerly been in flames; but that a very pious man, vicar of the village, had succeeded by his frequent aspersions of holy water in extinguishing the subterranean fire. They added that, since this time, the fiery volcano had become a watery volcano, *volcan de agua*. . . Without giving any credit to the existence of an extent of country in a former state of ignition, we were conducted by the Indians to the Volcancitos de Turbaco; and this excursion made us acquainted with phenomena much more important than any we could have expected. . . .

In the center of a vast plain, bordered by bromelia karatas, are eighteen or twenty small cones, in height not above seven or eight meters. These cones are formed of a blackish gray clay, and have an opening at their summits filled with water. On approaching these small craters a hollow but very distinct sound is heard at intervals, fifteen or eighteen seconds previous to the disengagement of a great quantity of air. The force with which this air rises above the surface of the water may lead us to suppose that it undergoes great pressure in the bowels of the Earth. I generally reckoned five explosions in two minutes; and this phenomenon is often attended with a muddy ejection. The Indians assured us that the forms of the cones undergo no visible change in a great number of years; but the ascending force of the gas and the frequency of the explosions appear to vary according to the seasons. I found by analyses made by means both of nitrous gas and of phosphorus, that the disengaged air scarcely contains a thousandth part of oxygen. It is azotic gas, much more pure than that which is generally prepared in our laboratories.[2]

[2] From "Researches concerning the Institutions and Monuments of the Ancient Inhabitants of America," by Alexander Humboldt. Vol. II, p. 95.

REALISTIC MINIATURE VOLCANOES

THESE TWO CRATERS ARE OF THE TYPE WHICH HAVE STEEP SIDES AND SMALL MOUTHS. THEY ARE IRREGULAR IN ERUPTION, BUT WHEN A DISCHARGE DOES TAKE PLACE IT IS MORE FORCEFUL THAN IN THE MORE PREDOMINANT TYPE.

THE MOUTH OF A FUMAROLE

SOME OF THE SEDGES SEEM TO THRIVE IN THE LIQUID MUD, GROWING ON THE CRESTS OF THE VOLCANOES.

A SPECIES OF ACHRIS WHICH SURROUNDS THE FIELD

THE TOUGH FIBERS OF MANY SPECIES ALLIED TO THIS ARE USED BY THE COLOMBIANS FOR MAKING ROPE.

It was with this description in mind that we traversed the muddy road from Turbaco. The vegetation of the region is made up of typical lowland thickets, overgrown with creepers and vines, often covered with brilliant morning glories. Occasionally huge trees rise out of the jungle, but these are exceptional. Palms occur in groves, but are not common.

In the midst of this tropic vegetation is the level space which forms the volcano field. The plain is rectangular in shape, about two hundred by five hundred yards. The soil of this region is a dark brown clay, which varies in consistency from a soft mud to a hard, caked surface. The area is more or less divided into three sections, which are separated from one another by irregular clumps of sedges. The entire field is bordered by a growth of a species of Achris (the "bromelia karatas" which Humboldt mentions).

It is possible that the number of craters varies from time to time, but at present there are between fifty and sixty active ones. Their dimensions as given by Humboldt are considerably exaggerated, due either to a change which has taken place in the last hundred years, or to the enthusiastic imagination of the old traveler. At any rate, at present the cones are elevated no more than three or four feet above the surface of the field, and many of them are even less.

In general there are two types of craters, the most predominant type being characterized by gradually sloping sides and a wide mouth, which varies in diameter from one to five feet. The cold and creamy liquid which fills these craters is usually continuous in its bubbling; it sometimes overflows the rim of the fumarole and runs down the sides, to harden in the glaring sun. The remaining volcanoes generally have much steeper crowns of mud and smaller mouths, sometimes only two or three inches in diameter. This type is often inactive, but occasional forceful eruptions eject streams of mud several inches

A THICKET COVERED WITH MORNING GLORIES

THE VEGETATION OF LOWLAND COLOMBIA IS PREDOMINATED BY THESE VIRILE VINES WITH THEIR MANY-HUED FLOWERS. IN THE REGION OF THE MUD-VOLCANOES THEY ARE PARTICULARLY WELL DEVELOPED.

into the air. The only sound which accompanies this disengagement of gas is a faint bubbling, as that of boiling water. One's first thought on viewing the liquid in the craters is that it is boiling, but examination proves that it is cold, and that the commotion is caused by gas passing through it.

Mud-volcanoes, or air-volcanoes, as they are often known, occur in several regions of the globe. There are two types: first, where the movement is caused by gaseous discharges, and second, where the active agent is steam. Those of Turbaco are an illustration of the former type. The cones themselves are formed by an accumulation of fine saline mud which is given out, with various gases, from a crater in the center. Gradually these outpourings of mud harden until a perfect miniature volcano is formed. Sometimes a hard tropic rain will wash down the small cones and spread the material over the ground, but new gas bubbles appear through the mud, and hence new cones are formed.

Thus it is seen that the origin of the gas is quite deep in the ground, and that by some chemical method it is freed from subterranean strata. Gases which are associated with mud-volcanoes are chiefly hydrocarbons, with more or less carburetted and sulphuretted hydrogen and nitrogen.

An analysis of the mud from the volcanoes of Turbaco shows little which is exceptional. The U. S. Bureau of Soils finds it to consist essentially of quartz and colloids (both as coatings on grains and as aggregates); with lesser amounts of muscovite, and very small amounts of biotite, tourmaline, orthoclase, calcite, and traces of zircon. (An analysis by Mr. W. H. Fry.)

SIR ISAAC NEWTON ON GRAVITATION

By Professor FLORIAN CAJORI
UNIVERSITY OF CALIFORNIA

Of all the scientific men of the world few, if any, have surpassed Sir Isaac Newton in the depth and importance of their discoveries. It is therefore very singular that some writers describing the achievements of Newton resort to exaggeration and to legend.

In the room in which Newton was born there is a tablet bearing Alexander Pope's lines,

> Nature and nature's laws lay hid in night
> God said, "Let Newton be" and all was light.

This statement indicates Pope's cleverness, but it lacks sincerity. "Nature's laws lay hid in night" ignores Kepler, who exercised extraordinary mathematical keenness in taking Tycho Brahe's observations on the positions of planets and from them deducing the three famous "Kepler's laws." The first of these laws states that the planets move in elliptical orbits having the sun at one of the foci; the second, that the straight line joining any planet with the sun moves over equal areas of space in equal periods of time; the third, that the squares of the times in which any two planets complete a revolution round the sun are proportional to the cubes of their mean distances from it.

Newton's earliest studies connected with Kepler's laws and with Kepler's book on optics. Had there been no Kepler there could have been no Newton as we know him; Newton would have been compelled to begin research further back and to have spent much effort on preliminaries. Newton's law of gravitation consigned to the scrap heap Descartes' theory of planetary mechanics, with its famous "vortices," and yet the general concept of Descartes was a philosophical contribution of prime importance to Newton. We mean the concept that celestial motions should be explained on mechanical principles and not on the primitive hypothesis of animism, according to which the planets are moved by spirits, benign or evil. The phrase "hid in night" also forgets that there was a Copernicus, that there was a Greek by the name of Aristarchus who two thousand years before Copernicus taught what is known as the "Copernican system." Again, the phrase forgets that the history of science exhibits torch-bearers all the way down the centuries, some torches, to be sure, being more brilliant than others.

The latter part of Pope's couplet claims too much. Like the first part, it is noteworthy only for the extravagance of its untruth. Of no man can it be said that, due to him, "all was light," for this implies that the end of questioning nature was reached, that there was no room for a Laplace and a Herschel, for a Newcomb and an Einstein. The highest poetry is not poetry of exaggeration, of gross distortion; the highest poetry is poetry of truth.

Other writers on Newton have indulged in the promulgation of legend; prose writers as well as poets have been guilty of that practice. Particularly is this true when writing about Newton's discovery of the law of gravitation. It is well known that about twenty years intervened between his first computation and his final announcement of the law. A vital question in the scientific career

of Newton is, what was the cause of this long delay? Here it appears as though the fates had conspired to distort the facts, to misrepresent the deep scientific questions which perplexed Newton, to ignore the intense intellectual struggle which alone could remove the difficulties which his profound mind saw but which lesser minds had overlooked. In the popular erroneous account of the progress of Newton's great discovery there is no room for such an intellectual struggle. His delay, so it is claimed, was due to a wrong value of the radius of the earth. When twenty years later the correct value was announced to him, a short computation revealed the law. How simple is this legendary story. The legendary account minifies the real achievement of Newton.

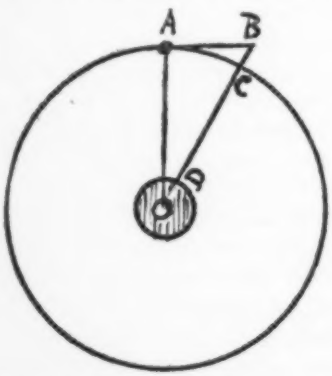
Newton's Computation of 1666

Let us state the facts regarding which there is general agreement. Newton had taken the degree of B.A. at Trinity College, Cambridge, early in 1665. He was then twenty-three years old. A dreadful plague broke out, the college was closed, and Newton returned to the country where he was born, in Lincolnshire, where he remained the larger part of nearly two years. Amusements so common in our day—the phonograph, cinema, radio, automobile—were unknown in his day. Thus a person inclined to silent contemplation was free to indulge in that luxury without undue distraction. Newton's mind dwelled upon problems in mathematics and he developed, as his notebooks indicate, the first notions of "fluxions," or what is now called the differential calculus. His mind dwelled also upon the cause of planetary motion, which had become a common topic of discussion among astronomers after Kepler had discovered his three laws about half a century earlier. Kepler's laws were purely descriptive in character. They were three isolated statements telling *how*, but not *why*. It was natural for scientists to search for an underlying and unifying principle. Kepler himself came very near the truth, for he realized that attraction between two bodies was mutual and proportional to the mass, and varied with the distance, but the exact law of variation escaped him. He supposed it to be the inverse distance instead of the inverse square of the distance. Newton deduced the law of inverse squares from Kepler's third law, by a process of mathematical analysis, a result which was independently reached by others. The curious reader may ask, what more remained to be done, to establish the law of gravitation? If this law was found to be a consequence of Kepler's third law of planetary motion, why not rest upon the oars and rejoice? But the matter was not quite so simple. In the first place, there remained reasonable doubt as to the accuracy of Kepler's third law. It had been established by induction. It was deduced from data on the positions of planets at successive periods of time. Observations are only approximate, hence the proof of a law is only approximate. Had the conclusions of Kepler been checked with sufficient care to warrant implicit acceptance? They had not.

In the second place, how should distance be measured in estimating the attraction between the sun and a planet? Should it be measured from surface to surface? Or from center to center, or from a point below the surface a third or half way to the center? No one had shown that one of these modes of measuring the distance was correct and all others were wrong. The planets were so far apart that a slight error in the terminal points of a distance does not matter much. But how would it be with large bodies in closer proximity? No one had settled the question. Evidently

scientists were justified in exercising skepticism.

So Newton, whose thoughts were not distracted in the quiet of his country retreat by radio or cinema, permitted his mind to dwell upon this interesting problem. Tradition has it that he saw an apple fall from a tree at his boyhood home and that this incident initiated a train of thought on gravitational attraction. No one can prove or disprove the truth of this story. There is nothing inherently improbable in it. However, at this time Newton's thoughts began to dwell upon the earth's attraction for the moon. Was the moon attracted to the earth by a force which varied according to the law of the inverse square of its distance from the earth? If so, can this be checked by mathematical computation? A simple process of computation was published twenty-one years later in Newton's "Principia." Presumably this is in substance the same process of reasoning as that followed by him in the computation of 1666. If in



some way he could find the distance BC (see figure) through which the moon falls toward the earth in a short period of time (say, a second), he could compute the distance a body, in the same period of time, would fall from rest at D, on the surface of the earth, according to the law of gravitation. The computed value could be then compared with the experimental value. It should be premised that if the moon moving at A were not attracted by the earth, it would travel in a straight line a distance AB in the time considered. But the earth pulls the moon down a distance BC, prevents the moon from "going off on a tangent," and causes it to move in a curved path. Newton had the means of computing BC. He knew the distance of the moon from the center of the earth to be very nearly sixty times the radius of the earth. He knew that the moon revolves around the earth once in twenty-seven days, seven hours and forty-three minutes. Hence he could compute the distance AC the moon travels in its orbit in a second, and also by geometry, the fall BC. Now would come the crucial test. If a body falls a distance BC when as remote as the moon, how far would it fall if it were at D, on the surface of the earth, sixty times nearer to the earth's center? If the law of attraction according to the inverse square of the distance is true, the fall at D should be sixty times sixty, or 3,600 times greater. But we know from actual measurement that a body falls from rest on the earth's surface nearly 16.1 feet in a second. Are the computed and experimental values the same? We do not know the details of Newton's computation in the year 1666. We do not know how accurately the computed and experimental values agreed. But we do know that about 1887 the astronomer J. C. Adams discovered in the Portsmouth Collection of Newtonian manuscripts a sheet in Newton's own handwriting and containing a reference to this computation, to the effect that in 1666 Newton "found them answer pretty nearly." Yet Newton delayed the announcement of the law of gravitation for twenty years. Why?

Legendary Account of the Discovery of Gravitation

When, after his death, Newton's career came to be surveyed, the cause of the twenty years' delay demanded explanation. Newton's letters to Halley, relating to a controversy between Newton and Robert Hooke on the priority of advancing the law of inverse squares in gravitational attraction, were not published at that time and were not generally known. One of the experimental data used in the computation of 1666 was the radius of the earth, by which the length of the moon's orbit was obtained. A gross error in the size of the earth would spoil the computation. Before Newton, there were varying estimates for the size of the earth, some fairly accurate, others far remote from the truth. According to the legendary account, Newton, by a tragedy of misfortune, used too small a value for the size of the earth. This popular account rests partly on statements of old age with its defective memory; the more correct account rests, as we shall see, upon statements written by Newton himself and made when he was in the prime of life. The popular version is due mainly to Henry Pemberton, who in 1728, the year after Newton's death, published "A View of Sir Isaac Newton's Philosophy." He states in the preface:

> It was in the very last years of Sir Isaac's life, that I had the honour of his acquaintance . . . he engaged me to take care of the new edition he was about making of his Principia. . . . Though his memory was much decayed, I found he perfectly understood his own writings. . . .
>
> Supposing therefore the power of gravity, when extended to the moon, to decrease in the same manner, he computed whether the force would be sufficient to keep the moon in her orbit. In this computation, being absent from books, he took the common estimate in use among geographers and seamen, before Norwood measured the earth, that 60 English miles were contained in one degree of latitude on the surface of the earth. But as this is a very faulty supposition, each degree containing about 69½ of our miles, his computation did not answer expectation; whence he concluded that some other cause must at least join with the action of the power of gravity on the moon. On this account he laid aside for that time any further thoughts upon this matter.

This explanation sounds very plausible.

The next step in the growth of this legend was the dramatization of Newton's behavior when Picard's exact earth-measurement, given out in 1671, became known to him. It is said that in repeating the earth-moon computation he was taken with such intense emotion that, to carry it to a finish, he had to secure the assistance of a friend. As a poet puts it:

> . . . his hand shook
> And dropped the pencil. "Work it out for me,"
> He cried to those around him; for the weight
> Of that celestial music overwhelmed him.

These seemingly plausible and poetic accounts do not rest upon sound foundation. The story of Newton's supposed intense emotion first appeared in 1804 in Dr. Robison's "Mechanical Philosophy," about one hundred and twenty years after Newton announced his great discovery.

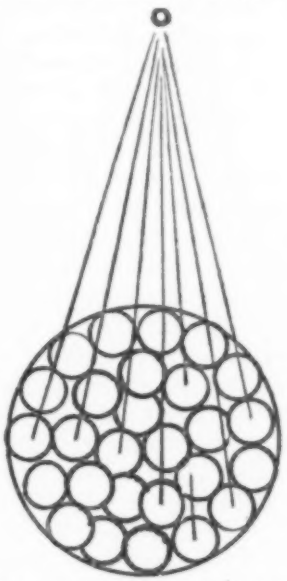
As to Pemberton's account, we have made an intensive study of it and have found it in conflict with certain historical facts and with Newton's own written statements. Pemberton says that Newton's computation of 1666 "did not answer expectation"; Newton himself said that he "found them answer pretty nearly." Pemberton refers to the size of the earth as estimated by English seamen, but he is mistaken as to the kind of miles used by seamen. They commonly took the degree of latitude to be sixty miles, not English statute miles of 5,280 feet each, as Pemberton claimed, but miles of 5,000 feet each. Newton himself, in his "Principia" used miles of 5,000 feet each. If in 1666 Newton

took, as Pemberton claims, the seamen's estimate of a degree, he used sixty miles of 5,000 feet each, when he should have used nearly 69.1 English statute miles of 5,280 feet each; his computed value would have differed from the experimental value by as much as 18 per cent. and he could not possibly have "found them answer pretty nearly." Such an expression of agreement would have been absurd. Again, Pemberton says that Newton was "absent from books," but Newton's account of expenses during 1665 and 1666 shows that he purchased "Gunter's Book and Sector." Most probably this was one of the books containing a description of the sector and cross-staff, wherein Gunter urges the adoption of Snell's careful measurements of the earth, made in the year 1617, which were equivalent to sixty-six and two-thirds English statute miles per degree. Most probably this was the value that Newton used in 1666. The answer would have been within 4 per cent. of the truth and might well have elicited the remark that he "found them answer pretty nearly." The rôle of this copy of Gunter's book in Newton's great discovery has been hitherto overlooked. Richard Norwood in 1636 had measured the distance between London and York and obtained a still more accurate value for the size of the earth. We do not know that in 1666 Newton was familiar with that estimate; its use would have reduced the error far below 4 per cent. We see that Pemberton lays all Newton's troubles relating to gravitation to his use of a wrong value for the size of the earth; Newton nowhere makes such a statement. He nowhere ascribes his delay to a wrong value for the earth's radius. But he does point to theoretical difficulties which at first he was not able to overcome.

Thus it appears that the popular story relating to Newton and gravitation and the cause of his delay in publishing the law is a gross distortion of the facts.

A Necessary Step in Proving the Law of Gravitation

What was the nature of Newton's difficulty? Why did he delay for twenty years the announcement of the law of gravitation? It was a difficulty in the theory which less profound thinkers had completely overlooked. It was the problem, how a homogeneous sphere attracts an outside particle (see figure).



In applying the gravitational hypothesis, should the distance be measured from the outside particle to the center of the earth, or to a point nearer or farther than the center? Primarily the force of gravitation acts between minute parts of bodies. Each small particle of the earth attracts the outside particle. These attractions are not all of the same intensity, because some particles are at a greater distance from the outside particle than others. Moreover, the directions of these attractions vary. It is a difficult mathematical problem to find the resultant of all these forces. It is a

subtle problem in the integral calculus. Nor is it easy to anticipate just what the result will be. Newton solved it in the year 1684. The result came out much simpler and more beautiful than he had expected. The distance must be measured from the *center* of the earth to the outside particle. Robert Hooke, who claimed the law of gravitation as his own prior discovery, had assumed all this without demonstration. In a letter dated June 20, 1686, Newton wrote to Halley: "There is so strong an objection against the accurateness of this proportion, that without my demonstrations to which Mr. Hooke is yet a stranger, it can not be believed by a judicious philosopher to be anywhere accurate." His theorem is proved in his "Principia," Book I, Proposition 71. Relating this important theorem, Dr. J. W. L. Glaisher wrote in 1888 at the bicentenary celebration of the publication of the "Principia": "No sooner had Newton proved this superb theorem —and we know from his own words that he had no expectation of so beautiful a result till it emerged from his mathematical investigation—than all the mechanism of the universe at once lay spread before him."

Publication of the "Principia"

Newton's intellectual interests were manifold. He worked in the fields of gravitation, optics, mechanics, comets, algebra, geometry, infinite series, fluxions, chemistry, biblical criticism—in fact in almost any intellectual realm which happened to strike his fancy. What circumstance directed him toward the preparation of the "Principia"? The answer to this important question involves the astronomer, Edmund Halley, who was the son of a soap manufacturer and was fourteen years younger than Newton. He had been a student at Queens College at Oxford. Interested in astronomy from boyhood, he went at the age of twenty to St. Helena to observe the positions of fixed stars in the southern heavens. Like other astronomers he was meditating on the problem of gravitation; he had come to admire Newton's powers, and in August, 1684, he went from London to Cambridge to ask Newton a question. He desired to know what would be the curve described by a planet on the supposition that gravity diminished as the square of the distance. Newton was able to answer instantaneously that the curve was an "ellipse," for some years earlier, in 1679, this question had arisen in his correspondence with Hooke and had been solved by him. Halley naturally desired to see the proof, but Newton, not being able to find his notes, promised to send the proof later. He worked it out again and, extending his researches, was able within three months to send Halley a manuscript containing eleven propositions on central forces. Halley saw the importance of the results and at once paid a second visit to Cambridge, to confer with Newton on the matter. Halley extracted from him the promise that he would communicate his researches on this subject to the Royal Society, of which he was a member. At a meeting of December 10, 1684, Halley gave an account of Newton's treatise on motion. Fortunately Newton continued work on this topic. About this time, or soon after, he proved the fundamental theorem on the attraction of a sphere upon an outside particle, that subtle problem which before this had baffled his best efforts. On April 28, 1685, the first book of the "Principia" was sent to the Royal Society. Newton was now working with an intensity of effort and a brilliancy of success seldom, if ever, equaled in the history of science. The second book of the "Principia" was finished in the summer of 1685. In March, 1687, Newton sent Halley the

second together with the third and final book of the "Principia."

At this time two events threatened to thwart the publication of the "Principia"; one was controversial in nature, the other financial. No sooner was Newton's first instalment presented to the Royal Society than Robert Hooke entered a claim of priority, the claim that the law of gravitation was his own earlier discovery and that Newton was indebted to him for it. Newton, who was always sensitive to criticism, was greatly disturbed and wrote Halley letters denying any such indebtedness and showing that his gravitational research was much earlier than that of Hooke. There is no doubt that Hooke had arrived at an *hypothesis* regarding gravitation, as had also Wren and Halley, but Newton was the only one possessing the penetrating genius which changed the hypothesis into a certainty. Newton also wrote Halley that he wished to withdraw from publication the third book of the "Principia," the very book which contains the application of abstract theory to the motions of the members of the planetary system, to the shape of the earth and to the tides. The tact and devotion of Halley saved the day; he succeeded in pacifying Newton so that the publication of the entire work was allowed to proceed.

As early as May 19, 1686, the Royal Society ordered that Newton's book be printed. One difficulty was encountered in carrying out this order; there was no money in the treasury! The society was issuing a book on the history of fishes, which had absorbed the available funds. Thus a book which does not in the least interest scientific men of the present day stood in the way of perhaps the greatest scientific book ever written. Science progress was on the verge of a real catastrophe. A tragedy of misfortune was impending. A second time Halley came to the rescue. The son of well-to-do parents, Halley had been accustomed in his earlier career to spend money freely. Although at this time he was less prosperous financially and, moreover, had a family to support, nevertheless he assumed the entire financial burden; as a mathematician and astronomer of real insight, he was fully able to recognize and admire the great merits of Newton's book. The second calamity was averted.

The reception of Newton's gravitational theory was not immediate, not even in England, or even in Cambridge. The "Principia" was not food for babes. An understanding of it called for mathematical training of a high order, and willingness to devote midnight oil to its mastery. The older and rival "theory of vortices" of Descartes, according to which the planets are carried around in their course, as is a chip of wood in an eddy of water, presented a picture at once comprehensible and satisfying to the uncritical mind. For about forty years after the publication of Newton's "Principia" in 1687, the Cartesian system maintained a foothold in England. Voltaire, who attended Newton's funeral, declared that at his death Newton had not above twenty followers in England. On the continent the vortices of Descartes were still in great favor, but by the middle of the eighteenth century they were being rapidly displaced by the Newtonian system. Since that time the celestial mechanics of Newton has held undisputed sway. Not even the relativity theory of Albert Einstein can claim to have upset it. That theory, if true, constitutes a generalization of Newton's system, not an overthrow of it.

THE RADIOACTIVE ELEMENTS

By Dr. L. R. KOLLER

RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

THE element radium, more than any of the other known elements which make up our world, has served to give mankind a knowledge of the nature of these elements and of the history of the world which they form. It has given us an insight into the structure of the atom and of the relations between the atoms of different elements. This has come about in two ways. First of all, through observation of the disintegration processes which the radioactive elements undergo; and secondly, by using as probes the swift alpha particles emitted by radium. These are shot out at a speed nearly one tenth of that of light and penetrate into the very hearts of atoms, and by their behavior give us much information regarding their structure. In addition, radium is making a large contribution to the physical welfare of man in the treatment of disease.

The radioactive elements manifest their presence in a number of different ways. They cause certain substances, such as zinc sulfide, to fluoresce in the dark. They blacken a photographic plate. Their most convenient manifestation, however, for both quantitative and qualitative scientific work is their ability to ionize gases. This is indicated by the rate at which an electroscope is discharged in the presence of radioactive material.

The characteristic that differentiates the radioactive elements from the other elements is their spontaneous disintegration. Before discussing disintegration, however, a few words concerning the structure of the atom will not be amiss.

According to the very earliest ideas matter consisted of small discrete particles or atoms. These atoms were supposed to be the very smallest particles that could exist; the particles that one obtained by subdividing matter until it could be subdivided no further. This was the generally prevailing view until the discovery of the radioactive elements. There had been other theories, but there was no evidence of an experimental nature to support them. With the discovery of the radioactive elements came the knowledge that the atoms were not the ultimate indivisible units of matter, but that they themselves could be split up into smaller units, namely, protons and electrons.

The electron is one of the ultimate constituents of all matter. It is the unit charge of negative electricity. Its presence was first shown in a conclusive manner by Sir J. J. Thomson in 1897. He showed that the so-called cathode rays really consisted of a stream of particles smaller than atoms which were always of the same size, regardless of how they were produced or from what they were produced.

We now know the mass and charge of the electron to a high degree of accuracy due to the measurements made by Professor R. A. Millikan.

The other constituent of all matter is the proton or positive charge of electricity. All the known kinds of matter are made up of these two kinds of building material, their differences being solely due to the relative numbers and arrangements of the protons and electrons.

Through the work of Sir J. J. Thomson, Sir Ernest Rutherford, Niels Bohr and many others, we have a very de-

tailed picture of this structure. Each atom consists of a nucleus of positive electricity in the center surrounded by one or more electrons rotating about it in elliptical orbits. The simplest atom of all is the hydrogen atom with a nucleus of one proton and a single electron rotating about it. Next in order of increasing size of nucleus is helium. The helium nucleus consists of four protons and two electrons, so that the net charge on the nucleus is two; and rotating about this are two electrons. Next comes lithium with a nucleus containing seven protons and four electrons, leaving a net charge of three on the nucleus, and rotating about it are three electrons, and so on.

The atom is always visualized as a minute solar system with a small compact sun composed of positive and negative charges (but always with an excess of the former) and planetary electrons rotating about the sun in numbers equal to the net positive charge on the nucleus.

The nucleus of the helium atom appears to be a very stable group and we often meet with this group of four protons and two electrons which is known as an alpha particle. In the last analysis, however, this too reduces to the ultimate units of protons and electrons.

To return to the history of the radioactive substances: After the discovery of X-rays search was made of many substances to determine whether they too might not emit a penetrating radiation. Henri Becquerel performed some experiments on uranium which showed that it possessed the power of emitting a very penetrating radiation. He placed some of the salts of uranium in a black paper on top of a photographic plate and interposed between the two a piece of silver. He found on the plate a photograph of the silver. Further experiments showed that the radiation from the uranium which acted upon the photographic plate was capable of passing through thin pieces of glass and other materials. Becquerel also showed that these rays emitted by uranium possessed the power of discharging an electroscope. Later thorium was found to possess this same property.

Mme. Curie studied this behavior in a large number of substances containing uranium and thorium. She found some specimens of the mineral pitchblende which showed an activity four to five times that of uranium. Since she had already shown that this behavior was always strictly proportional to the amount of the element present, and since the activity of these substances was more than that corresponding to the amount of uranium present, some other highly active unknown substance must be present. Further work proved the correctness of this hypothesis and led to the discovery of the new element radium.

It is a very heavy metallic element. Its most remarkable properties are those centering around its disintegration. Radium is found to have the property of acting on a photographic plate and of causing the discharge of an electroscope. A detailed investigation of this behavior showed that the radium radiation is complex and is of three kinds, now called alpha, beta and gamma rays. These rays are being constantly given off by the radium at a rate entirely independent of any external conditions, such as temperature or pressure.

The alpha rays have been shown to be nothing other than atoms of helium projected from the radium atom with enormous velocities, some as high as one tenth of that of the velocity of light. The beta rays are electrons hurled from the atom with even greater speeds than the alpha particles. It is not surprising that with speeds such as these particles can penetrate considerable thicknesses of matter. Nor is it surprising that in the atomic cataclysm which leads to the

ejection of these two particles a disturbance is set up in the ether which gives rise to a very penetrating X-ray of very short wave-length known as the γ-ray.

We may consider these radiations from two points of view; their effect on the atom from which they came; and on the matter through which they pass.

Let us first consider what happens to the radium atom when it gives off radiation. What it is that causes this remarkable phenomenon we do not know, we are only able to observe what takes place and to measure the rate at which it occurs. We know that out of the 2.7×10^{21} atoms in one gram of radium 3.4×10^{10} will disintegrate per second. At this rate in 1.730 years half of the original quantity of radium would have broken up.

When an alpha particle is ejected the nucleus loses the two positive charges associated with it and so there must be a rearrangement of the electrons in the surrounding orbits. The new atom is lighter than the old one by the weight of the alpha particle which it has ejected. Its atomic number, as the number of positive charges in the nucleus is called, is smaller by two and its chemical and physical properties are no longer the same. It is a new substance. It is called radon (radium emanation) and happens to be a gas. This atom, like its parent, is unstable and after a time emits an alpha particle and forms a new substance known as radium A. Radium A eventually passes into radium B. Radium B manifests its instability in a slightly different fashion by emitting an electron or beta ray and so the process continues until eventually a product is attained which is stable and undergoes no further changes. This product is lead. It is only a matter of time before each atom of radium will become an atom of lead.

Similar processes take place in atoms of other radioactive elements. It is this characteristic of disintegration that distinguishes the atoms of the radioactive substances from the other elements. They are continually undergoing change and passing from an atom of one kind of substance to an entirely new substance. It is this behavior and its explanation by Professors Rutherford and Soddy that gave the first proof that an atom was not a simple entity but a complex one, and that by some kind of rearrangement it could be changed into another substance. What takes place in the atoms of the radioactive elements is the realization of the dreams of the alchemists, the transmutation of the elements.

There is still another way in which the radioactive elements have given us an insight into the structure of matter, due to the work of Sir Ernest Rutherford and his coworkers in the Cavendish Laboratories. The alpha particles shot off from radioactive atoms have been used as probes with which to search deep into the centers of other kinds of atoms. This method has been very fruitful and has given much information regarding the sizes and weights and atomic numbers of atomic nuclei.

It has been possible by bombarding atoms with swift flying alpha particles to partially disintegrate them. Thus we have not only been able to observe the transmutation of the elements taking place in the radioactive series, but we have even been able to cause it to take place at will in other substances, if only on a very small scale.

In the hands of the physicist and chemist radium has been a powerful tool. In the hands of the medical man it is in its infancy as an aid to the treatment of disease, particularly malignant growths such as cancer.

If we but knew how to control disintegration of this kind and cause it to take place at will, the engineer might find in a few grams of matter the energy for which he now has to consume tons of fuel and our whole economic system and daily life might be revolutionized.

SHIPS

By Professor EZRA BOWEN
LAFAYETTE COLLEGE

IT is generally supposed that harbors, ready cargoes and an abundance of shipbuilding materials make a great shipping nation. But there have been nations which possessed all these qualifications in the first degree, and which at the same time had almost no shipping business. On the other hand Holland, for example, with no important source of cargoes or shipbuilding materials had at one time almost a monopoly of the world's shipping trade. The ships of Norway, the most intensely maritime of modern nations, make comparatively little use of home harbors. Nowhere in the literature of history or of economics are these things explained.

Let us see if we can not apply the method of science to the enigma—proceed exactly as would the chemist or geologist or diagnostician. First, we shall isolate and define our problem. Next we shall try to form an hypothesis that explains it. Then, by assembling the greatest possible number of similar instances, we shall test this hypothesis to see if it is worthy of future detailed study. Let us try it.

Our problem, stated in simplest terms, is: What is the key circumstance which forces or leads nations to develop a great overseas carrying trade?

An hypothesis is an intelligent guess, not a random shot, but a conjectured explanation based on experience. It should rest upon a rather wide experience, the experience of actual contact or, where that is impossible, the second-hand experience of reading and study. But an hypothesis, however intricate and extensive or simple and special and in whatever science, is nothing more or less than a thoughtful conjecture from experience.

The following hypothesis is not offered of course as a single peg upon which to hang the whole of sea history. Other explanations of the presence or absence of a carrying trade—such as an abundance, or lack of harbors, cargoes, shipbuilding materials—are entirely valid. What we now offer is merely a collateral hypothesis which may prove upon further investigation to be founded upon a universal and key circumstance: Nations do not develop an overseas carrying trade until they are forced to; mankind does not go to sea except by necessity; man is not a marine animal. A nation develops an overseas carrying trade only when other outlets for economic activity are absent or have been destroyed.

Having defined our problem and presented our rather simple hypothesis, the next step in the process is to test this hypothesis by induction: we must turn back through the pages of history and assemble a complete array of nations which have, as a matter of clear and definite record, established an important overseas carrying trade, and find if in every instance they have lacked adequate outlets for economic activity.

The first nation to develop a notable merchant marine and to secure the bulk of the world's carrying trade was the Phoenician.[1] Phoenicia, a narrow strip of territory extending along the eastern shore of the Mediterranean, was well situated for trade with the dominant civi-

[1] Day, Clive, "A History of Commerce," p. 13.

lized countries of the time.[2] Tyre and Sidon were its principal cities. Both were on barren rocky islands near the coast.[3] The Phoenicians, a highly developed people, made extensive voyages and furnished reliable means of sea transport. They learned to direct their course at night by the North Star, which was called by the Greeks the Phoenician Star. Their ships were for centuries the accepted models of naval design.[4] They were the discoverers of the western Mediterranean; it was the Phoenicians who brought the first rudiments of civilization to Spain.[5] Just before the opening of the Christian era, King Necho sent out an expedition to attempt a circumnavigation of the continent of Africa. He also started to dig a canal across the Isthmus of Suez. The canal was afterward completed—nearly two thousand years before Benjamin Disraeli, a near relative of the Phoenicians, put a backbone into the amorphous British Empire by acquiring the Suez Canal.[6]

This great seafaring people, the first seafaring people to whom the term great could possibly be applied, lived upon a coastal plain not more than two hundred miles long and about twenty miles wide.[7] Natural resources were scarce, grazing was poor and farming worse.[8] Agriculture and the trades were soon overcrowded and this energetic people, hemmed in between sea and mountains, was literally forced into the sea.[9] "They could gain a scanty food supply from the level ground, and had timber in abundance on the mountains that separated them from the interior, but had to look to trade with other peoples for the means of growth which their home denied them."[10]

Greece was the next nation in the world's history to develop an important overseas carrying trade.[11] The foreign trade of very ancient Greece was carried entirely in Phoenician ships.[12] The Greeks were a pastoral people according to Breasted, who finds Hesiod (700 B. C.), the peasant poet, "looking with a shrinking eye upon the Sea."[13] The pre-Hellenic Greeks produced an exportable surplus of oil and wine, but a rapidly growing population soon met with a deficiency in many products, especially in grain and other fundamentals.[14] It was not until population had outrun the agricultural possibilities of a fairly fertile—but extremely hilly and rocky—land that any considerable carrying trade was developed.[15] Miletus was the first of the Greek cities in commercial importance. The people of this Carian city were cut off by surrounding mountains from nearly all economic activity by shipping and fishing—a situation a great deal like that of Genoa, a city destined to attain great commercial importance some centuries later.[16] The little island of Aegina, rocky and sterile, supporting even to-day but six thousand inhabitants, became for a time the most

[2] Knight, M. M., "Economic History of Europe," 1926, pp. 28–29.

[3] Botsford, G. W., "A History of the Ancient World," p. 39.

[4] Breasted, J. H., "A History of the Early World," pp. 287–8.

[5] Hall, Edward Everitt and Susan, "Spain," p. 17.

[6] Holt and Chilton, "European History, 1862–1914," pp. 192–3.

[7] Stephenson, J., "The Principles and Practice of Commerce," p. 106.

[8] Botsford, G. W., "A History of the Ancient World," p. 39.

[9] Botsford, *loc. cit.*

[10] Day, Clive, "A History of Commerce," p. 12.

[11] The term Greece is used to indicate all the Hellenic regions.

[12] Day, *op. cit.*, p. 18.

[13] Breasted, J. H., "A History of the Early World," p. 259.

[14] Rostovtzeff, "A History of the Ancient World," p. 371.

[15] Breasted, J. H., "A History of the Early World," p. 287.

[16] *Encyclopedia Britannica*, Eleventh Ed., *Art.*, Caria.

important market of the Greek world; it amassed fabulous riches from a commerce penetrating all seas.[17] In the case of Greece, the second notable shipping nation of the world, we find—as with Phoenicia—that an energetic people soon exhausted the rather meager agricultural opportunities of its native land and was forced to go down to the sea in ships.

During the early Middle Ages shipping and navigation, along with many other arts and sciences, languished.[18] Only in the far north, in Scandinavia, do we find a truly seafaring people, during these long centuries when the world's pulse beat so feebly—when the world was slowly convalescing from its first heavy attack of civilization. These hardy northern sea-rovers sent out ships in every direction over the cold gray Atlantic—to Iceland, to Greenland and, five hundred years before Columbus, to North America.[19]

But the Norsemen were not a commercial people; they were fishermen and raiders.[20] They put out in tiny, open boats looking for new fishing grounds, where fat fish were to be had for the taking, or new raiding grounds, where fat farmers and burghers could be despoiled of their properties.[21] We know what worthy ships they used, for one was discovered a few years ago in a burial mound in southern Norway, where it had been preserved, it is supposed, since the ninth century.[22]

From the time when ancient Greece attained her greatest glory, there were centuries, therefore, during which sea traffic languished, and no nation developed an important merchant marine. Finally Byzantium, or rather Megara (Constantinople), became the world's shipping center.[23] Constantinople was handicapped economically—as Tyre and Sidon, Miletus and, later, Genoa and Pisa—by a rocky broken terrain, constricted territory and pressing border of towering hills. The Byzantians also were squeezed out upon the sea.

Then Constantinople yielded primacy to Venice, whose rich merchants sent their captains to every corner of the known world.[24] The origin of this medieval city-state can be traced to the "barbarian invasions," when people from the mainland of Europe were driven to find refuge upon islands in the lagoons of the north shore of the Adriatic. But only the scantiest living was obtainable on these meager footholds,[25] and the fugitives were "*forced*[26] to seek a living upon the sea, first as fishermen but more and more as merchants."[27]

The Venetian fleet was the finest and the Venetian navy was the most powerful in the world. In 1268 Venice presented to France ships that were 110 feet over all, carried a complement of more than one hundred men and must have measured four or five hundred tons, while English ships of the period rarely exceeded fifty or one hundred tons.[28] England, later to become mistress of the seas and to retain that position for a longer time than any nation, was in the Middle Ages very unimportant.[29] The

[17] Day, Clive, "A History of Commerce," p. 19.

[18] Thatcher and Schwill, "Europe in the Middle Ages," pp. 436–7.

[19] Du Chaillu, P. B., "The Viking Age," Vol. II, p. 518, *ff.*

[20] *Cf.* Thatcher and Schwill, *op. cit.*, chap. ix–x.

[21] *Cf.* Haskins, C. H., "The Normans in European History," chap. i and ii.

[22] Day, Clive, "A History of Commerce," p. 70.

[23] "Cambridge Medieval History," Givatkin and Whitney, Eds., Vol. III, p. 762.

[24] Bemont and Monod, "Medieval Europe," p. 349.

[25] Lodge, R., "The Close of the Middle Ages," p. 140.

[26] Italics ours.

[27] Day, *op. cit.*, p. 90. (Italics ours.)

[28] Day, Clive, "A History of Commerce," p. 72.

[29] *Cf.* Cutts, E. L., "Scenes and Characters of the Middle Ages," pp. 461–518.

"fact" that the seafaring disposition is "in the blood of Englishmen" is more than questionable: to the contrary, it appears that Englishmen, as other men, did not go to sea until circumstances left scant choice. Like Phoenicia—and later, Great Britain—Venice developed and consolidated her commercial supremacy by establishing many and far-flung colonies. Through this practice she controlled the commerce of the Mediterranean even more efficiently than Great Britain controlled the commerce of the world in the nineteenth century—though of course the field of opportunity was much narrower.[30] The entire citizenry of Venice was engaged in commerce or trade.[31]

Genoa and Pisa were the commercial rivals of Venice.[32] Both were situated on the steep, rocky west coast of Italy, where agriculture in any substantial sense was impossible. Each had a hinterland of unyielding mountainous country which cut off its inhabitants from any employment except the working of gardens hewn out of rocky hillsides—though with a small river valley to the south and east, the Pisan background was the less difficult. These people were "forced," no less than the citizens of Venice, to seek a living upon the sea.

Spain was the next nation to strut her hour upon the commercial stage and to develop an important overseas carrying trade.[33] Now Spain differed from these other nations, Phoenicia, Greece, Byzantium, Venice, Genoa and Pisa, with their constricted territory, their precarious foothold upon a narrow shore: Spain was a great broad land, but it is easy to overdraw the agricultural opportunities of Spain. She has, throughout most of her history, been more of a grazing than an agricultural land,[34] and it is well known among economists that a grazing economy supports far fewer persons per square mile than almost any other.[35] Over the entire area, the annual rainfall of Spain is less than twenty inches.[36] A great part of the land is rugged, mountainous, unyielding.[37] Toward the end of the Middle Ages, soil exhaustion and the invasions of the Moors—a series of long, bitter wars—had almost totally wrecked Spain's economy. Manufacture and resources fell almost wholly into the hands of Moors and Hebrews.[38] It was then that Spain began to look seaward and to develop, later, a notable merchant marine—when opportunities for other forms of economic activity were either wrecked, exhausted or preempted. Spain, like Phoenicia, Greece and Venice before her, and England and Holland afterward, developed and consolidated her overseas carrying trade by the acquisition of colonies; but Spain never reached the peak of commercial dominance attained by those nations.

Portugal, during the fifteenth and sixteenth centuries, became a power in overseas trade.[39] Her commerce was not only large in proportion to her area and population, but equaled the trade of the greatest nations in the world.[40] At the close of the Middle Ages, Portugal had a population of scarcely more than a million—perhaps even less.[41] Her car-

[30] Thatcher and McNeal, "Europe in the Middle Ages," pp. 294–5, 432.

[31] Grant, A. J., "A History of Europe," p. 381.

[32] "Cambridge Medieval History," Vol. III, p. 762, Vol. V, pp. 226–7.

[33] Burke, "A History of Spain," p. 325.

[34] *Cf.* Hume, M. A. S., "The Spanish People," chap. viii.

[35] Ratzel, F., "History of Mankind," (translated from 2d German Ed.), Vol. 1, p. 10.

[36] Smith, J. Russell, "Industrial and Commercial Geography," p. 422.

[37] Chisholm, G. G., "Handbook of Commercial Geography," p. 444.

[38] *Cf.* Hume, *loc. cit.*, also Day, "A History of Commerce," pp. 174–5.

[39] Smith, Preserved, "The Age of the Reformation," p. 524.

[40] Stephens, H. M., "Portugal," p. 156.

[41] Smith, *op. cit.*, p. 458.

rying trade soon began to rival Spain's and to surpass, by far, the commerce of any northern European state.[42] In the middle of the fifteenth century Portuguese caravels were recognized as the best sailing ships in the world.[43] Here again we have a mountainous, meager soil, unsuited for any form of production but grazing, wine-raising and arboriculture.[44] The ports of Lisbon and Orporto, backed as they were by rocky hills extending up and away to the bleak and desolate Serra da Estrella, were located almost exactly as the great Italian ports of the preceding century, Genoa and Pisa—and the Phoenician ports of Tyre and Sidon. The inhabitants of Portugal were forced from their narrow footing on the coast of the Iberian Peninsula by rocky hills and steep mountain slopes; they were compelled to become a seafaring people by circumstances much like those which surrounded the Phoenicians, Genoese and Pisans. After Portugal, the Netherlands assumed primacy in the world's carrying trade.[45]

There are no mountains in Holland, quite true; but the thrifty, energetic Dutch people were hemmed in, none the less: powerful neighbors confined Holland to a small swampy area, fit only for precarious grazing and a rather limited agriculture. The soil was rich, but it had to be drained at great pains and expense; the well-known thoroughness with which this was done is complete evidence of the scarcity of agricultural opportunities.[46] During the war for independence there was a notable increase in population.[47] Clive Day says: "The Dutch were forced to the sea by the difficulties of life at home. . . . Before 1602, sixty-five ships had made the return voyage to India and throughout the 17th century an active commerce was maintained both with Asia and America."[48]

Holland developed a merchant marine greater than the fleets of any nation before her, and came nearer to obtaining a monopoly of the world's commerce than any nation since the day when "the world" meant the shores of the Mediterranean.[49] We learn that the Dutch owned four fifths of all ships engaged in ocean commerce and that ten Dutch ships traded to the Barbadoes for one English.[50] In proportion to number of inhabitants and extent of natural resources, the Dutch developed the most magnificent commerce of any nation after the Phoenicians and the Venetians. More ships were built in Holland than in all the yards of Europe.[51] Here again —as with Venice—we have a people living upon constricted swampy land, meagerly endowed with natural resources, cut off from large economic opportunities.[52] They went to sea—not because of fine harbors or abundant shipbuilding materials or because "it was in their blood"—the Dutch set out upon the broad ocean because circumstances forced a seafaring life upon them.

The seventeenth century saw the rise of another poor, small nation to a position of commercial power. In 1600 England had scarcely four million inhabitants.[53] Throughout the sixteenth century she was counted a poor nation.[54]

[42] Day, Clive, "A History of Commerce," p. 184.

[43] Egerton, H. E., "The Origin and Growth of Greater Britain," p. 27.

[44] Chisholm, G. G., "Handbook of Commercial Geography," pp. 446–7.

[45] Smith, *op. cit.*, p. 442.

[46] Lyde, L. W., "The Continent of Europe," pp. 263–4, 267.

[47] Webster, W. C., "A General History of Commerce," p. 146.

[48] Day, Clive, "A History of Commerce," pp. 190–1.

[49] Egerton, H. E., "The Origin and Growth of Greater Britain," pp. 49–50.

[50] Day, *op. cit.*, p. 223.

[51] Webster, W. C., "A General History of Commerce," p. 148.

[52] Chisholm, G. G., "Handbook of Commercial Geography," p. 373.

[53] Smith, Preserved, "The Age of the Reformation," p. 453.

[54] Green, J. R., "Short History of the English People," pp. 326–7.

Climate favored grazing rather than tillage; mineral resources were still largely unknown and therefore of little value. As late as the reign of Elizabeth, England imported almost all "artificiality," as finished manufactures were called.[55] At the beginning of the eighteenth century, wool was still her largest export.[56] It was from these meager circumstances that England developed a supremacy in the carrying trade that lasted the better part of four centuries and which remains undisputed. But it is very important to remember—and almost nowhere is it fully appreciated—that during the Middle Ages the English were not great navigators in spite of the facilities offered by excellent harbors and rivers penetrating far inland.[57] English ships were miserable little traps, far outclassed by those of Norway, Venice, Pisa and Genoa.[58] English commerce was largely in the hands of foreigners.[59] It was not until the population of England began to outgrow agricultural opportunities that her people turned their eyes seaward. In the bitter competition for commercial supremacy which ensued between the British and the Dutch, Great Britain triumphed. The shock and burden of conflict with the declining power of France and the rising power of England shattered Holland's commercial supremacy.[60] But the Dutch merchant marine is still notable; on a per capita basis it is surpassed to-day by few.[61]

Which nations, in modern times, have the largest per capita ship tonnage—which nations, in proportion to size, have developed the most important merchant fleets? They are, in the order named, Norway, Great Britain, Holland, Denmark, Sweden.

PER CAPITA TONNAGE IN MERCHANT FLEETS OF LEADING NATIONS

	Per capita tonnage	Population[62]	Tonnage[62]
(1) Norway	.964	2,650,000	2,555,000
(2) Great Britain	.448	42,920,000	19,274,000
(3) Holland	.353	7,315,000	2,585,000
(4) Denmark	.295	3,419,000	1,008,000
(5) Sweden	.201	6,036,000	1,215,000
(6) United States[63]	.099	117,823,000	11,605,000
(7) France	.083	39,400,000	3,262,000
(8) Italy	.075	38,755,000	2,894,000
(9) Japan	.061	61,082,000	3,741,000
(10) Germany	.048	62,539,000	2,893,000

Norway is a rugged, bleak land; gorgeously beautiful for a few fine days in summer, in winter it is dreary.[64] Lumbering, hunting, trapping and, in a limited sense, dairying and agriculture are the only possible occupations.[65] Towering snow-topped mountains rise directly from the sea, forming the jagged fjords which make such excellent harbors. The whole country is mountainous and rocky; 75 per cent. of its area is unproductive and 22 per cent. is in forest[66]—in brief, a land which seems especially designed to make a life upon the sea appear attractive. Here in Norway we find the seafaring life developed to its highest pitch—possibly the highest pitch reached in the whole history of man's effort to make a living. England is a great seafaring nation, but the per

[55] Smith, *op. cit.*, p. 535.

[56] Webster, W. C., "A General History of Commerce," p. 172.

[57] Williamson, J. A., "Maritime Enterprise," chap. xiii.

[58] *Cf.* Cutts E. L., "Scenes and Charts of the Middle Age," pp. 416–474.

[59] Williamson, *op. cit.*, pp. 16, 19.

[60] Webster, W. C., "A General History of Commerce," p. 164.

[61] See table, *infra*.

[62] "The Statesman's Year-Book," 1926.

[63] Included in this reckoning are about six million tons of coastwise shipping. If this were excluded the United States should rank tenth.

[64] Lyde, L. W., "The Continent of Europe," p. 111.

[65] Huntington and Williams, "Business Geography," p. 250.

[66] Smith, J. Russell, "Industrial and Commercial Geography," p. 441.

capita tonnage of little Norway is more than twice as great.

The industrial revolution meant more to Great Britain than to any other land.[67] But the opportunities for earning a living, which were opened up by the development of industrialism, were soon exhausted by a rapidly growing population, and throughout the nineteenth century, the heyday of industrialism, a nearly constant emigration from the British Isles indicated a sufficient scarcity of domestic, economic opportunities to insure the attractiveness of a seafaring career.[68] The first full burst of industrialism could not offer sufficient attraction during the early part of the nineteenth century to counterbalance an interest in shipping that had been gaining momentum for two hundred years and by the end of the century a teeming and vigorous population produced a demand for jobs which far outran the home supply.[69]

Modern Holland has about the same economic opportunities—or lack of them—as medieval Holland (Netherlands), save that territory is even more narrowly constricted. The result, as we see from the table, is that modern Holland also has developed a notable merchant marine. Mineral resources are almost wholly wanting; bad natural drainage makes agriculture difficult.[70] The climate is not pleasant.[71] Her struggles with France and England took from Holland leadership in the world's carrying trade, but did not remove the key incentive to the development of an important overseas commerce, the lack of domestic, economic opportunities. Her carrying trade returned.

Denmark's agricultural possibilities exceed Norway's and are but little inferior to England's or Holland's, but compared with the more favored nations of the earth, Denmark yields meager returns to economic endeavor. Natural resources—other than a capable and courageous population, which is probably the handsomest resource a nation may possess—are entirely lacking.[72] Farming is carried out upon what is practically a synthetic soil.[73]

Sweden has less than a quarter the per capita merchant tonnage of Norway; but she owns more than twice as much as her nearest rival; we need go no further. The ratio of Norway's per capita tonnage to Sweden's is four to one in favor of Norway: opportunities for economic activity at home are probably well represented by the reverse ratio of four to one in favor of Sweden.[74] In Sweden there is iron and there are other mineral resources, but not in profusion, and there is no coal.[75] Sweden has fertile valleys, but the land is hilly and rocky[76]—less productive, on the average, than land in Denmark or Great Britain. The climate of Sweden is not pleasant; rain or snow falls during a large part of the long winter. Her days are not shrouded in darkness and rain during four months of the year as with northern and western Norway; still Swedish winters are far from attractive.[77]

In testing our hypothesis, by the inductive method, we have assembled all instances of notable seafaring nations

[67] Dietz, F. C., "The Industrial Revolution," pp. 23–4.

[68] Egerton, H. E., "The Origin and Growth of Greater Britain," pp. 8–9.

[69] Demangeon, A., "The British Empire," pp. 63–4; Egerton, *op. cit.*, says (p. 215) that from 1910–14 emigrants to Canada alone numbered 614,088.

[70] Chisholm, G. G., "Handbook of Commercial Geography," pp. 373–4.

[71] Lyde, L. W., "The Continent of Europe," p. 267.

[72] Smith, J. Russell, "Industrial and Commercial Geography," pp. 156–7.

[73] Smith, *loc. cit.*

[74] Chisholm, G. G., "Handbook of Commercial Geography," p. 436.

[75] Huntington and Cushing, "Principles of Human Geography," pp. 8–179.

[76] Chisholm, *loc. cit.*

[77] Smith, J. Russell, *op. cit.*, p. 144.

that appear in history. Beginning with the Phoenicians of 1500 B. C., every great tribe of sea-rovers has come under our view: the Phoenicians, the ancient Greeks, the Byzantians, the ancient Scandinavians, the Venetians, the Genoese, the Pisans, the Portuguese, the medieval Dutch, the seventeenth, eighteenth and nineteenth century English, the modern Norwegian, British, Dutch, Danish and Swedish peoples. In every case we found a people living of course upon a seacoast having at least one usable harbor; but many peoples that could not possibly be included in our array of important carrying nations were so situated. The common factor, the key factor, in every case appeared to be a lack of sufficient outlets for economic activity; in most cases we found economic opportunities upon a starvation basis. We found, in brief, that *a nation develops an overseas carrying trade only when other outlets for economic activity are absent or have been destroyed.* But this is not to deny of course that harbors, cargoes, shipbuilding materials and an energetic population are fundamental factors in the development of a merchant marine: here is merely a collateral hypothesis which suggests that these are not enough, and that to ensure a nation's developing a notable carrying trade there must be an unattractive domestic ecography.

This brief essay does not pretend of course to be a piece of historical research —all facts presented are common knowledge: it pretends to be no more than an exercise in the interpretation of history, leading to a perhaps not wholly valueless hypothesis of the rise and fall of merchant fleets, in no instance have we gone behind our authorities, and it is possible that every case cited offers an opening for further research, which might either strengthen or utterly destroy our hypothesis. Certainly the case of China, a land rich in resources—with splendid harbors, cargoes, a wealth of shipbuilding materials, and with navigable rivers extending far inland, and which nevertheless has owned very little shipping—could bear further research. Then there are the North Coast Africans; in this case there is no possibility of the seafaring-blood hypothesis' coming to bear. The region was repeopled at various times by the most widely differing human strains: Phoenicians, Moors and even Vandals. In every case a notable sea trade flourished. How did Vandals from the dense woods of Central Europe or the dry Hungarian plain develop in a generation the "seafaring instinct"? Here is another opportunity for research. Should this little essay initiate inquiry into these and other instances and into the general hypothesis submitted it will have reached its furthest aim.

FOOD PREJUDICES

By Dr. CHARLES W. TOWNSEND
IPSWICH, MASSACHUSETTS

THE educated cosmopolite does not hesitate to try strange foods. Not so the savage, the child and the ignorant. In these three classes, food prejudices—often curious and irrational—abound. In California, a man and woman sitting near me in the car expressed great curiosity about the immense fields of blue-green French artichokes. I explained what these vegetables were, how they were served and eaten, dwelt on their toothsomeness and recommended a trial. "Oh, no!" said the man with the utmost finality, "We never eat strange foods."

Here spoke the cosmopolite's "contemporary ancestor." In a hostile world the savage must take heed what he eats or he may rue the day. Although many of his food taboos are doubtless fanciful, others are based on substantial reasons. One of his remote ancestors may have experimented with a strange food and was poisoned by it, and the tradition has become fixed in the tribe. An overripe oyster may cause death, while venison, aged in the cache, may be a nourishing delicacy. His tribes for generations have known what foods are good and he avoids all others—all "strange foods." Food prejudices to-day, therefore, are due to inheritance from our savage ancestry; they are atavistic.

On both the American and European shores of the Atlantic Ocean two shellfish are common, the soft-shelled clam, *Mya arenaria*, and the edible mussel, *Mytilus edulis*. The species of these two mollusks are the same on both sides of the water. In Europe, mussels are eaten freely but not clams, while the reverse is the case on the American side. This prejudice, against the mussel here and against the clam there, extends back to prehistoric times, for while clam shells abound here in kitchen middens or ancient shell heaps and mussel shells are merely accidental, in Europe the exact opposite is the case.

Professor Edward S. Morse, in his study of the changes in the shell of the clam,[1] was amazed to find no clam shells in the Baltic shell heaps, while the living mollusks abounded in the nearby estuaries. The prehistoric people like their modern successors did not eat the clam. He adds: "It was the same in England; the clam had never been eaten, even in ancient times. It is a common shell there, and thousands of barrels are shipped to the Newfoundland fisheries for bait. We learned the epicurean delights of the clam from the North American Indians." In a recent visit on the Norfolk coast of England I had great difficulty in persuading a company of educated English people to taste the clam!

Children are nearer the savage state, more atavistic than their educated parents, and strange foods are often to them abominations. The wise parent instils the precept, "Eat what is set before you and be thankful," and, to take the sting off, he may add, with a twinkle in his eye, "put your food into your mouth and not into your lap." The unwise parent allows the innate talent for food prejudices to grow strong in his young hopefuls, and even boasts that his little Johnny or Mary can not eat this and can

[1] SCIENTIFIC MONTHLY, xxi, 1925, p. 424.

not eat that. I do not refer here to certain rare idiosyncrasies, as, for example, when even a minute amount of egg causes symptoms of poisoning, for that fortunately does not often happen to Johnny and Mary, and they have no inborn prejudices which warn them against such food. Food prejudices run rife among them. It may be observed, as in the case of the travelers and the French artichoke, that the victim does not even taste the food that falls under his taboo. His mind is made up without that. He *knows* the food is not fit for him to eat, and the fact that others eat it and enjoy it and thrive makes no difference.

The third class mentioned above, the ignorant, is well represented—or rather used to be—by the peasant servant girl who was content with corned beef and cabbage, and refused even to taste venison and wild duck.

All of us are very near the savage state, for our civilized ancestry is but a minute fraction of our whole human ancestry. Food prejudices, therefore, abound even among the educated. In the matter of fish, this is strikingly the case. In England and in this country the various kinds of flatfish, whether known as sole, plaice or flounder, are considered good and delicate eating and bring a high price either in the market or restaurant. This is not the case in the Gaspé Peninsula, in Newfoundland and in Labrador. In Newfoundland I once read an editorial in a St. John's paper urging the use of this fish as a food and recounting the fact—singular to Newfoundlanders—that the flounder brought high prices in the States. At Grand Grève in Gaspesia I told a fisherman and his wife, at whose house I was staying, the high esteem and high price in which the flounder was held in Boston, and suggested that the next he caught should not be wasted. I am afraid I damaged my reputation for truthfulness by mentioning the price. A few days later I saw several flounders deposited as fertilizer in the garden, and, on my exclaiming at the sacrilege, he said, "Oh, they are not fit to eat!" There was nothing more to be said.

In my youth, when on codfishing excursions I caught pollack, no matter how large and fine, I was told to return them to the water as they were "not fit to eat." Nowadays this prejudice seems to have disappeared. At Grand Manan, New Brunswick, haddock and hake were formerly thrown away, and nearly everywhere along our coasts the dogfish, hated by fishermen for the damage it does to fish and nets and bait, is destroyed and cast out. It is true that it has an unpleasant name for a food fish—for there is much in a name, Shakespeare to the contrary notwithstanding—and it is also true that the dogfish is a shark, but let me add that it has firm white flesh which is nearly as good eating as that of the esteemed swordfish. The first time that I determined to try the gastronomic qualities of this fish and had expected to be obliged to prepare and cook it myself, I was agreeably surprised to find that our cook, a native of the Hebrides, welcomed it as an old friend and prepared a savory dish of it. For some reason the inhabitants of the Hebrides, or at least of that part from which she came, had no prejudices against the dogfish. To avoid this prejudice, the names "gray fish" and "rock salmon" are used here and in England.

It may be thought that the knowledge of the food on which the fish or other creatures live has a great deal to do with food prejudices, but when we consider the food of the domestic hen and of the domestic pig, it is hard to conceive of anything worse. Make no inquiry as to the food of the lobster!

Norman Heathcote, in "Birds of St. Kilda," says that the favorite dish at this island was "skate which was begin-

ning to go bad." Parenthetically, I might remark that we prefer our game "when it is beginning to go bad," and I might add that the skate like the dogfish is a kind of shark.

In Labrador, young gulls are considered great delicacies as food, while the mere idea of eating cormorants is a thing abhorrent, yet gulls feed on the flotsam and jetsam of the sea, on long-dead fish as well as on fresh ones. Cormorants, on the other hand, feed exclusively on freshly caught fish. On a cruise along the Labrador coast I once broiled the breast of one of these birds. The two sailors turned away from it in horror—I had not been able to persuade one of them, the cook, to prepare it—but the captain, a broad-minded man and one who could rise above prejudices, much to his surprise, found it delicious, as, indeed, it was. It is possible that the uncanny neck of this bird with the bare patch of orange-colored skin at the throat has something to do with the prejudice, but no one objects to the turkey which has a still more uncanny head and neck.

To "eat crow" has an unpleasant metaphorical flavor. Equally unpleasant, even abhorrent to most people, is the idea of eating crow in the literal sense. The crow stands at the head of the bird world in brain capacity. He has no food prejudices, but his bill of fare is dainty compared with that of the barnyard fowl. Now I can assert that a properly broiled or roasted crow, especially if young, compares well with pigeon or squab. Very few, I am convinced, would approach the subject with an unprejudiced mind or palate, so that, no doubt, the experiment would fail, to my discomfiture, but I can add that I have found some to agree with me. Fair judgment in such matters is difficult or impossible to the victim of food prejudices. It is conceivable that honey might taste to him like vinegar. Rook shooting and rook eating in Pickwick's time, at least, was common sport in England. A rook is a crow.

I remember reading a sportsman's recipe for cooking porcupine which included long stewings and changes of water. The recipe concluded with the advice—which was excellent under the circumstances—to throw it all away without serving. A nicely broiled porcupine steak or hind quarter, I can, however, aver from experience, to be excellent. The same can be said of woodchuck, muskrat and skunk; I have tried them all. Indians are particularly fond of skunk, which, be it added, is known in the Algonquin tongue as *shikago*—tell it not in Gath!

Explorers in savage regions often learn to divest themselves of food prejudices. Captain G. F. Lyon, of H. M. S. *Hecla*, in a voyage of discovery in the Arctic regions under Captain Parry, was a good example. He says, "All were horrified at the idea of eating foxes, but very many got the better of their delicacy and found them good eating. Not being myself very nice, I soon made the experiment, and found the flesh much resembling that of kid, and afterwards frequently had a supper of it."

Captain George Cartwright, who lived from 1770 to 1786 on the Labrador coast, was another such adventurous soul. He found his men rebelled at being made to eat venison in winter in order to conserve the salt pork which they preferred, and only by an artifice did he get them to eat polar bear.

Stefansson, in "The Friendly Arctic," gives a very good account of food prejudices among Esquimau dogs. He found that the dogs brought up far from the sea and fed on caribou and rabbit would not eat seal meat, while those brought up on the seashore and used to seal meat would not touch other game when they were taken inland. He found that in young dogs the prejudice was more

quickly overcome than in old dogs who would sometimes endure starvation rather than try the new food, and that old females were the most obstinate in refusing to give up their prejudices. This leads him to conclude—rather ungallantly, perhaps—that "this seems to extend the commonly believed-in principle of the greater conservatism of human females down into the lower animals." The highly civilized dog, used to all kinds of foods, has, as is obvious, few or no food prejudices.[2]

It is well known that the introduction of potatoes and tomatoes in Europe was a slow and difficult process, and that Indian corn meal is even now considered fit only for poultry in most parts of the British Isles, while the introduction of grapefruit as a part of the breakfast ritual has met with considerable opposition. In Labrador, turnip greens are eaten, but beet greens are thrown away.

Food prejudices are not limited to the savage, the child and the ignorant. They are found even among the intelligent and educated. An extreme case I discovered recently in an intelligent and educated man over threescore years of age. He admitted that he was much spoiled as a child and that until he was twenty-one he had refused to taste any vegetable but the potato. After this he gradually overcame many of his vegetable prejudices, but he still refuses to eat or even taste beets. The reason he can not give unless it be its color, but he admits that this is unreasonable, for he is very fond of strawberries. Of banana, watermelon and cantaloupe he has never even tasted, and he shudders to think of trying them. Although he lives in the pie belt and is fond of apple pie, he can not bring himself to try squash or pumpkin pie. How many good things in life this man has missed owing to his treasured food prejudices! How much better for him had he been brought up to eat the food set before him and be thankful, even if he did put some of the food into his lap!

[2] See also Stefansson's article on "Food Prejudices" in the SCIENTIFIC MONTHLY, xi, 1920, p. 540.

AGRICULTURAL MAGIC

By GRACE M. ZIEGLER

TRENTON, N. J.

THE history of the establishment of a scientific agriculture has been similar to that of medicine and other sciences: a series of experiments and discoveries, with beliefs based upon apparent results. Before any mechanical aids to experimentation were known, and when there were no records of facts to guide experimental activities, efforts to improve conditions were extraordinarily crude and intermingled with magical rites and ceremonies. Modern writers have sought to show an interrelationship between magic and science, and some have gone so far as to state that modern science is an outgrowth from primitive magic.

Using the term "magic" in the sense that marvelous results were believed to be produced by impossible methods, we find that in early times it formed a part of the daily life and routine of every household. With the beginning of the Roman empire, however, there began to appear evidences, not so much of a disbelief in magic as of an apologetic attitude toward it. Pliny, while making a bold pretense of disbelief, nevertheless includes in his "Natural History" scores of magical recipes, some of which he declares to be true from his own observations. Similarly, a belief in supernatural powers was maintained by some of the most learned men from the beginning of the Christian era to the end of the Middle Ages, when Joan of Arc was burned as a witch in France in the fifteenth century, and on down to the seventeenth century, when the Salem witchcraft delusion in our own country was countenanced and concurred in by political and intellectual leaders as well as by the general public.

Thus in the second century it is interesting to find Plutarch giving magical formulas in Egypt; Isidore, of Seville, in the seventh century in *Etymologies* believing that marvels could be effected through magic by the aid of demons; Alexander Neckam, in *De Naturis Rerum*, in the twelfth century attributing marvelous powers to herbs, fountains, stones and even words; Roger Bacon, in the thirteenth century, advocating the pursuit of alchemy as a means of disproving and blotting out all magical nonsense and possessing a strong belief in astrology.

Albertus Magnus believed in the wondrous virtues of stones to cure ulcers, counteract potions, conciliate human hearts and win battles. To him was attributed a remarkable story which is significant of the credulity of the thirteenth century.

> William, earl of Holland, and king of the Romans, was expected at a certain time to pass through Cologne. Albertus had set his heart upon obtaining from this prince the cession of a certain tract of land upon which to erect a convent. The better to succeed in his application, he conceived the following scheme. He invited the prince on his journey to partake of a magnificent entertainment. To the surprise of everybody, when the prince arrived, he found the preparations for the banquet spread in the open air. It was in the depth of winter, when the earth was bound up in frost, and the whole face of things was covered with snow. The attendants of the court were mortified, and began to express their discontent in loud murmurs. No sooner, however, was the king, with Albertus, and his courtiers seated at table, than the snow instantly disappeared, the temperature of summer showed itself, and the sun burst forth with a dazzling splendour. The ground became covered with the richest verdure; the trees were clothed at once with foliage, flowers, and fruits: and a vintage of the richest grapes, accompanied with a ravishing odour, invited

the spectators to partake. A thousand birds sang on every branch. A train of pages showed themselves, fresh and graceful in person and attire, and were ready diligently to supply the wants of all, while every one was struck with astonishment as to who they were and from whence they came. The guests were obliged to throw off their upper garments the better to cool themselves. The whole assembly was delighted with their entertainment, and Albertus easily gained his suit of the king. Presently after, the banquet disappeared; all was wintry and solitary as before.[1]

These writers are mentioned merely as representative, and one could continue with a long list of well-known names, whose works are typical of the learning of their times and yet abound with curious beliefs. Astrology was taught in the medieval universities as the climax of mathematics and an essential part of medicine. In 1664, Sir Matthew Hale, presiding at a trial which resulted in the execution of two old women, said that there was no doubt that there was such a thing as witchcraft, which opinion was supported by Sir Thomas Browne, author of *Religio Medici* and other works, who was also present.

With even the most erudite maintaining the strange beliefs that gold might be coined from copper, the future foretold by the stars, problems of philosophy solved and nature controlled by invoking demons, it is not surprising that the principal industry of the land, agriculture, should have employed mystical rites and ceremonies to secure good crops, to combat the enemies of crops, to produce rain or to stop it, to avert hail and in general to regulate production through magic. It is difficult, however, to see any relationship between such practices and agricultural science as it is employed to-day, unless it may be that those men who were farthest advanced in their knowledge of the supposed bonds of sympathy between different things or of the effects of lucky objects and methods or of the meanings of portents tried to support their claims by finding a true basis for improvement. This theory is supported by Pliny, of whom Lynn Thorndike[2] says, "Magi stand out in Pliny's pages not as mere sorcerers or enchanters, but as those who have gone farthest and in most detail—too curiously, in his opinion—into the study of nature." Thorndike himself found that "magicians were perhaps the first to experiment," and Sir James Frazer[3] calls magicians "the only professional class" among the lowest savages, stating that "they were the direct predecessors, not merely of our physicians and surgeons, but of our investigators and discoverers in every branch of natural science. They began work which has since been carried to such glorious and beneficent issues by their successors in after ages; and if the beginning was poor and feeble, this is to be imputed to the inevitable difficulties which beset the path of knowledge rather than to the natural incapacity or wilful fraud of the men themselves." However that may be, the use of magic in early agriculture forms an entertaining study.

Among the earliest beliefs is that of the corn spirit, or the embodiment of a mystical spirit or life in the new corn and the new fruits. Coincident with this belief was the observance of the sacrament of the first fruits, or the eating of the corn spirit, which is sometimes represented in human form and sometimes in animal form. Many instances have been found of the sacramental eating of animals at harvest time, while occasional examples among the savages have been discovered of the killing of human representatives in a spirit of sacrifice. The corn spirit, however, was usually considered to reside in the last sheaf of the grain and to eat a loaf

[1] Godwin, William H., "Lives of the Necromancers" (New York, 1835).

[2] Thorndike, Lynn, "Magic and Experimental Science" (New York, 1923).

[3] Frazer, Sir James, "The Golden Bough," abr. (New York, 1923).

made of the last sheaf was to eat the spirit itself. For example, in Scotland and in Sweden, the last sheaf was made into a loaf in the shape of a woman and little girl, respectively, and eaten sacramentally by the family. Similarly, in La Palisse, France, a man made of dough was hung upon a fir-tree carried on the last harvest wagon, and both taken to the mayor's house. After the harvest was over the dough-man was broken in pieces by the mayor and given to the people to eat. The solemnity accompanying such rituals is evidence of the desire to propitiate the corn spirit so that a plentiful harvest might be had the following year.

While the sacramental eating of the first fruits continued in certain localities for centuries, a later belief developed in which the fruits of the earth were conceived as created rather than as animated by a divinity. In line with this belief, a portion of the products were offered to the gods producing them, probably at first to provide sustenance for the gods, but later the offerings were made in a spirit of homage, or tribute. Many of the ancient deities of vegetation were worshiped by such conciliatory sacrifices: the Athenians and other Greek peoples offering the first wheat and barley harvests to Demeter and Persephone at Eleusis; the Romans sacrificing the first ears of corn to Ceres and the first of the new wine to Liber, with none of the people daring to eat of the new corn or drink the new wine until these sacrifices had been offered by the priests.

Isis and Osiris were worshiped in Egypt in connection with the production of food. Egyptian agriculture depended upon the annual inundation of the Nile, and at the rising of the river there was celebrated the festival of Isis, who was mourning for Osiris, for if there was too much water, or too little, a famine would result. Frazer described an illustration in the temple of Isis at Philae which explained the connection Osiris was supposed to have with the harvest.

> Here we see the dead body of Osiris with stalks of corn springing from it, while a priest waters the stalks from a pitcher which he holds in his hand. The accompanying inscription sets forth that "This is the form of him whom one may not name, Osiris of the mysteries, who springs from the returning waters." Taken together the picture and the words seem to leave no doubt that Osiris was here conceived and represented as a personification of the corn which springs from the fields after they have been fertilized by the inundation. This, according to the inscription, was the kernel of the mysteries, the innermost secret revealed to the initiated. So in the rites of Demeter at Eleusis a reaped ear of corn was exhibited to the worshippers as the central mystery of their religion. We can now fully understand why at the great festival of sowing in the month of Khoiak the priests used to bury effigies of Osiris made of earth and corn. When these effigies were taken up again at the end of a year or of a shorter interval, the corn would be found to have sprouted from the body of Osiris, and this sprouting of the grain would be hailed as an omen, or rather as the cause, of the growth of the crops.

Rejoicing at harvest-time was not permitted the Egyptian, for in cutting the grain he was severing the body of the corn-god and in threshing it was trampled to pieces. Accordingly, when the first sheaf was cut, it was the farmers' custom to beat their breasts and lament, calling upon Isis in the form of a melancholy chant. Similar lamentations for the corn-god killed by the sickles of the reapers were offered in Phoenicia and other parts of Western Asia.

The magical rites and ceremonies performed at planting and harvest time to ensure good crops ranged from simple treatments of seed or fields to elaborate ceremonials lasting several days and participated in by entire communities. Likewise, the enemies of crops had each its own magical remedy—too much or too little rainfall, hail, vermin, diseases and other causes of infertility.

With Pliny making a show of disbelief in magic, the more elaborate rituals are not referred to by him, but scores of the

simpler miraculous remedies are scattered through his work. He says, for instance:

As for other seed-corne it will escape the danger of the worme, if it . . . be sowed in and about the change of the Moone, namely, when she is not to be seene above the earth in our hemisphere. Many there be who practise other remedies: and namely for Millet, they would have a toad to be carried round about the field before that it be harrowed; which done, to bee put close within an earthen pot, and so buried in the middest of the said field: and by this meanes forsooth, neither Sparrows will lie upon the corne, nor any worme hurt it. Marie, in any case this same toad must be digged out of the ground againe before the field bee mowed, else will the Millet proove bitter in tast. The like experiment they say is of a Moldwarpes shoulder, for if any corne be sowed or touched therewith before, it will come up the better and bring more encrease. . . . But what remedie against the blast and mildew, the greatest plague that can befall upon corne? Mary pricke downe certain Lawrell boughs here and there among the standing corne, all the said mists and mildews will leave the corne and passe to the Bay leaves, and there settle.[4]

Of the weather conditions as affecting crops Pliny for the most part warily quotes previous writers:

Varro affirmeth, That if about the retrait of Harpe-star Fidicula, which is the beginning of Autumne, a man paint a cluster of grapes, and consecrate it to the gods among the Vines, the stormes and tempests of wind and raine will do lesse harme to the fruit hanging thereupon. *Archibius* in a booke that hee wrote to King Antiochus, saith, That if a landtoad be put into a new earthen pot that never was occupied before & the same enterrèd and covered within the ground in the middest of a corne field, the corne shall take no harme that yeare by any tempests whatsoever. . . . In Persia they are persuaded, That a perfume of such Agathes, turneth away tempests and all extraordinarie impressions of the aire, as also staieth the violent streame and rage of rivers. But to know which is proper for this purpose, they use to cast them into a cauldron of seething water: for if they coole the same, it is an argument that they be right. But to be sure that they may doe good, they must be worne tied by the haires of a Lions mane. . . . If it happen to thunder about the feast Vulcanalia, Figges will fall from the tree. The remedie thereof is to strew the plots before with Barley straw.

With the right amount of rainfall having such an important effect upon agriculture, it is not surprising that methods of producing rain, or of stopping it, were sought after and some curious devices practiced. Thus, for example, "in a village near Dorpat, in Russia, when rain was much wanted," Frazer tells us, "three men used to climb up the fir-trees of an old sacred grove. One of them drummed with a hammer on a kettle or small cask to imitate thunder; the second knocked two fire-brands together and made the sparks fly, to imitate lightning; and the third, who was called 'the rain-maker,' had a bunch of twigs with which he sprinkled water from a vessel on all sides." He also tells of other interesting beliefs regarding the production of rain:

It is said that the Aymara Indians often make little images of frogs and other aquatic animals and place them on the tops of the hills as a means of bringing down rain. The Thompson Indians of British Columbia and some people in Europe think that to kill a frog will cause rain to fall. In order to procure rain people of low caste in the Central Provinces of India will tie a frog to a rod covered with green leaves and branches of the *nim* tree (*Azadirachta Indica*) and carry it from door to door singing:

"Send soon, O frog, the jewel of water!
And ripen the wheat and millet in the field."

A few examples of practices of the North American Indians from the same author are interesting.

Amongst the Omaha Indians of North America, when the corn is withering for want of rain, the members of the sacred Buffalo Society fill a large vessel with water and dance four times round it. One of them drinks some of the water and spirts it into the air, making a fine spray in imitation of a mist or drizzling rain. Then he upsets the vessel, spilling the water on the ground; whereupon the dancers fall down and drink up the water, getting mud all over their faces. Lastly, they squirt the water into the air, making a fine mist. This saves the corn. In spring-time the Natchez of North America used to club together to pur-

[4] Pliny, "Historia Naturalis" (Holland trans., London, 1601).

chase favourable weather for their crops from the wizards. If rain was needed, the wizards fasted and danced with pipes full of water in their mouths. The pipes were perforated like the nozzle of a watering-can, and through the holes the rain-maker blew the water towards that part of the sky where the clouds hung heaviest. But if fine weather was wanted, he mounted the roof of his hut, and with extended arms, blowing with all his might, he beckoned to the clouds to pass by.

In Morocco, ball-games of the hockey type are played for rain-making purposes, the idea being that the rapid movements of the ball and the players will induce movement of the clouds.

Of incantations used to avert hail-storms, Pliny asserts that he would not dare seriously to repeat the words, although Cato, in his work on agriculture, had prescribed a similar formula of meaningless words to cure the fractured limbs of animals. It may be interesting here to insert this remedy, which was found in a translation of some of the works of Cato and Varro by "A Virginia Farmer":

If a bone is dislocated it can be made sound by this incantation. Take a green reed four or five feet long, split it down the middle and let two men hold the pieces against your hips. Begin to chant as follows:

"In Alio. S. F. Motas Vaeta,
Daries Dardaries Astataries Dissunapiter."

and continue until the free ends of the reed are brought slowly together in front of you. Meanwhile, wave a knife above the reeds, and when they come together and one touches the other, seize them in your hand and cut them right and left. These pieces of reed bound upon a dislocated or fractured bone will cure it. But every day repeat the incantation, or in place of it this one:

"Huat Hanat Huat
Ista Pista Sista
Domiabo Damnaustra."

To protect crops from the ravages of vermin, Pliny says:

This I am sure upon mine owne knowledge, that there is an herbe (but what proper name it hath I wote not) which if it bee enterred in the foure corners of a field that is sowne with Millet, it will drive away Stares and Sparrows, which otherwise would by whole flights and flockes lie thereupon and doe much harme: nay I will speake a greater word and which may seeme wonderfull, There is not a bird of the aire one or other, that dare enter or approach such a field.

Among the European peasants we find many superstitious devices to propitiate or quell the vermin. Again quoting Frazer:

Amongst the Saxons of Transylvania, in order to keep sparrows from the corn, the sower begins by throwing the first handful of seed backwards over his head, saying, "That is for you, sparrows." To guard the corn against the attacks of leaf-flies (*Erdflöhe*) he shuts his eyes and scatters three handfuls of oats in different directions. Having made this offering to the leaf-flies he feels sure that they will spare the corn. A Transylvanian way of securing the crops against all birds, beasts, and insects, is this: after he has finished sowing, the sower goes once more from end to end of the field imitating the gesture of sowing, but with an empty hand. As he does so he says, "I sow this for the animals; I sow it for everything that flies and creeps, that walks and stands, that sings and springs, etc."

Again we are told:

The mouse is one of the most dreaded enemies of the rice-crop in Celebes. Many therefore are the prayers and incantations which prudent farmers resort to for the purpose of keeping the vermin from their fields. Thus, for example, a man will run round his field, saying, "Pruner is your name. Creep not through my rice. Be blind and deaf. Creep not through my rice. If you must creep through rice, go and creep through other rice." The following formula is equally effective: "Pruner is your real name. Mouse is your by-name. Down in the evening land is the stone on which you ought to sit; in the west, in Java, is your abode."

Another mode of getting rid of vermin and other noxious creatures without hurting their feelings or shewing them disrespect is to make images of them. Apollonius of Tyana is said to have cleared Antioch of scorpions by making a bronze image of a scorpion and burying it under a small pillar in the middle of the city. Further, it is reported that he freed Constantinople from flies by means of a bronze fly, and from gnats by means of a bronze gnat. In the Middle Ages Virgil passed for an enchanter and is said to have rid Naples of flies and grasshoppers by bronze or copper images of these insects; and when the waters of the city were infested by Leeches, he made

a golden leech, which put a stop to the plague . . . Gregory of Tours tells us that the city of Paris used to be free of dormice and serpents, but that in his lifetime, while they were cleaning a sewer, they found a bronze serpent and a bronze dormouse and removed them. "Since then," adds the good bishop, "dormice and serpents without number have been seen in Paris."

In Albania, if the fields or vineyards are ravaged by locusts or beetles, some of the women will assemble with dishevelled hair, catch a few of the insects, and march with them in a funeral procession to a spring or stream, in which they drown the creatures. Then one of the women sings, "O locusts and beetles who have left us bereaved," and the dirge is taken up and repeated by all the women in chorus. Thus by celebrating the obsequies of a few locusts and beetles, they hope to bring about the death of them all.

Amulets had a place in agriculture as well as in the general life of the people. The agate was considered an agricultural amulet, and it was recommended that it be attached to the plowman's arm and the horns of the oxen. Plutarch tells of a sort of poppy which grew in a river of Mysia and bore black, harp-shaped stones which the natives gathered and scattered over their ploughed fields. If these stones then lay still in the fields a barren year was signified, but if they flew away like locusts, a plentiful harvest was forecast. Pliny ascribes to the powers of stones such virtues as to benefit public speakers, admit to the presence of royalty, counteract fascination and sorcery, avert hail, thunderbolts, storms, locusts, and scorpions; chill boiling water, produce family discord, render athletes invincible, quench anger and violence, make one invisible, evoke images of the gods and shades from the infernal regions. In the thirteenth century Vincent, of Beauvais, medieval encyclopedist and author of *Speculum Maius,* stated that agates would avert storms and thunderbolts, give victory in war, rout venomous animals, aid the sight, slake the thirst and promote fidelity. He further said that the *balagius* would stimulate conjugal affection, burn the right hand grasping it, strengthen weak eyes if one drinks water in which it has lain, and protect against enemies. Coral is said by him to check hemorrhage, reduce corpulence, draw harmful humors from the eye, etc. Suspended from trees or sown with seed he believed it would protect the fruit or crops from hailstorms.

Astrology also had its place in agriculture. Pliny says:

Howbeit, wee cannot chuse but confesse, that the true reason and knowledge of agriculture, dependeth principally upon the observation of the order in heavenly bodies. Certes, a hard peece of worke it is, and infinite; and small hope I have that ever I shall be able to drive into their heads that are so ignorant and grosse of conceit, this high learning and heavenly divinitie as touching the planets, the fixed Starres, together with the reason of their orderly motions and coelestiall powers: Howbeit considering the great profit that may arise and grow thereupon to mankind, I will cast a proffer and give the attempt to make ploughmen Astrologers, or Astronomers at leastwise, if it may be.

Democritus, Pliny tells us, was able to corner the olive crop by his knowledge of astrology (which he calls astronomy) and "put to shame business men who had been decrying philosophy," and on another occasion to give his brother timely warning of an impending storm.

Probably the most numerous and elaborate agricultural festivals were celebrated at planting and harvest time, although there are many instances of magical practices performed by herdsmen and farmers at all periods of the year, and it is safe to say that no nation has been without its annual agricultural rituals. Space does not permit a description of these elaborate ceremonials, many of which have been practiced among the peasants in all parts of Europe even up to the beginning of the nineteenth century. They include the rites performed on Plow Monday in England; Shrove Tuesday in various parts of Europe, with carnivals similar in type in Bulgaria and other Thracian prov-

inces; and the fire-festivals practiced throughout all the area between Ireland and Russia and from Norway and Sweden to Spain and Greece. There were Lenten Fires, Easter Fires, Midsummer Fires, Hallowe'en Fires and Midwinter Fires, even the latter having an agricultural significance. The bringing of the Yule log is still solemnly observed by the southern Slavs, who seem to think that they will have as many calves, lambs, pigs and kids as they are able to strike sparks from the burning log. In some places a piece of the log is carried out to the fields to protect them against hail. There was also a "need fire," also called "wild fire" or "living fire," which was denounced in the eighth century by the Churches as a heathen custom, but which continued down to the first half of the nineteenth century in parts of England, Scotland, Ireland and Germany.

This custom of kindling great bonfires, dancing and leaping over them and driving cattle through or round them, together with processions or races in which blazing torches were carried round fields, orchards, pastures or cattle stalls, was believed to promote the growth of crops and the welfare of man and beast, either positively by stimulating them or negatively by averting dangers and calamities, witchcraft, blight, mildew, disease, etc. The "need fires" were resorted to especially when the cattle were attacked by an epidemic disease but were used whenever distress or calamity threatened.

The North American Indians also had their elaborate festivals, among which were the *busk* or festival of the first fruits, lasting eight days, and the Green Corn Dance of the Seminole Indians of Florida, which lasted many days and continued into the nineteenth century.

Dancing occupied a prominent place in all the ceremonials, and there was a common belief apparent in widely separated countries that dancing with high leaps and jumps would stimulate the crops to grow as high as the dancers leaped.

Magic, however, was not always believed to be practiced with beneficent intent, and consequently there is the paradox of magic being practiced to counteract magic. Down to modern times in eastern Europe when cattle were turned out to pasture in the spring, festivals were held on the twenty-third of April, St. George's Day, to protect the animals against the machinations of witches, as well as the ravages of wolves and other wild beasts. Among the South Slavs the herdsman crowns the horns of his cows with garlands of flowers to guard them against witchcraft, and in the evening the garlands are hung on the doors of the stalls, where they remain until the next St. George's Day. Early in the morning of that day, when the herdsman drives the cows from the byres, the housewife takes salt in one hand and a potsherd with glowing coals in the other. The salt is offered to the cow, and the beast must step over the smouldering coals on which various kinds of roses are smoking. By this means the witches are deprived of all power to harm the cow.

Instances of injury to livestock by magic were cited in our own country as late as 1692, in the famous Salem witchcraft trials in Massachusetts when such men as Governor William Phipps and Increase Mather, president of Harvard College, gave credence to the charges that due to the anger of one Bridget Bishop a pig was "taken with strange Fits; Jumping, Leaping and Knocking her Head against the Fence; she seem'd Blind and Deaf, and would neither Eat nor be Suck'd . . . and sundry other Circumstances concurred, which made the Deponents believe that *Bishop* had bewitched it."[5] Figuring in the trial of Susanna Martin were the charges that

[5] Mather, Cotton, "The Wonders of the Invisible World," (London, 1862).

she caused fourteen oxen to rush into the Merrimac River, all of which were drowned but one; that because she objected to the exchange of a cow with her son she caused this tame creature to grow "so mad, that they could scarce get her along. She broke all the Ropes that were fastned unto her, and though she were ty'd fast unto a Tree, yet she made her escape, and gave them such further trouble, as they could ascribe to no cause but Witchcraft"; that the cattle of one Bernard Peache were bewitched to death; that another complainant had lost cattle in one spring to the value of thirty pounds, following her threats.

Any selection of examples of magic that might be chosen from the various fields of study would show the same trend in the mental processes through which humanity has passed on its road to civilization. In the very beginning, when the struggle for food was instinctive, the simple acts performed without reason by individuals became group habits, and group habits became established customs. Without means of communicating their experiences to each other, and consequently with no basis of knowledge, the various groups gained their beliefs from false inferences relating to any accidental happening; and since the greatest care might sometimes result in failure and calamity, and lack of care at other times result in good fortune, there entered the aleatory element, or the belief that good or ill luck was due to the agency of ghosts or spirits, dependent upon the pleasure or displeasure of the superior powers at the acts of man. It took hundreds of years to overcome such beliefs by the aid of reason and to gain the knowledge, step by step, that has made possible the agriculture of to-day. Even yet research work has much to accomplish in this as in all other branches of learning, and processes are still taking place in the replacement of false practices by acts based on scientific knowledge, for which research facilities are available to an extent unknown in any period of the past.

BIRDS AND OTHER CHECKS UPON INSECTS

By W. L. McATEE

U. S. BIOLOGICAL SURVEY

THE article by Professor E. H. Strickland in the SCIENTIFIC MONTHLY for January, 1928, entitled "Can Birds hold Injurious Insects in Check?" fails to acknowledge that it was arguments founded on the economic value of birds that made possible the present very satisfactory American code of laws for bird protection. Professor Strickland implies that he is one who would protect birds for humanitarian and esthetic reasons, and he should accordingly be pleased that they are at present so well protected, even though this condition was brought about mainly by economic considerations. He need have no fear that bird lovers are a dying race, in fact their number was never greater than at present, and bird protection can be effectively urged to-day for esthetic reasons which would, however, have had very little appeal forty or fifty years ago when the groundwork of American bird protection was being laid.

In the course of his article, Professor Strickland points out certain principles of natural philosophy, applying them in a restricted way to the relations of phytophagous insects, their parasites, and bird predators, but weakens the whole texture of his argument by failing to take into account the universality of their application.

The general principles as to the fecundity of insects pointed out by our author apply also to birds. If a bird of average size lays four or eight eggs yearly, it would if unchecked use up (its greater capacity considered) the available food supply, or on account of its greater bulk actually fill up the available space (due to the same inexorable geometrical progression,) and reach these limits in all probability just about as quickly as would an insect. All that, however, is merely theoretical, for the expanding groups meet competition in every direction and are checked by a multitude of adverse factors, so that their potentialities for increase are never realized. As a result of these great checking forces all but a very small proportion of each generation of a fecund species perishes, but the law applies throughout, whether to plant-feeders, parasites or what not.

Mortality statistics are the same for birds as for insects, or any other organisms, and barring fluctuations in the balance of nature there are only enough survivors of each species to replace the parent population. Among the factors causing the mortality of insects, those directly or indirectly due to climate are by far the most important.[1] It is an exaggeration to give parasites first rank, as our author does, among factors exercising general control over the insect population.

It should not be forgotten that essentially parasites are dependents. It is farthest from their object to exterminate their hosts, even in a limited area. This result, which in most cases means disaster to the parasite, is, on the other hand, of but little moment to predacious insects or birds. The latter always have a wide range of prey, and even if one food supply is exhausted usually there are others at hand. The best evidence that

[1] See Marlatt, C. L., Bul. 20, n. s. U. S. Div. Ent., 1899, pp. 73–76; Scott, W. M., *ibid.*, pp. 82–85; and Chittenden, F. H., Bul. 22, n. s., U. S. Div. Ent., 1900, pp. 51–64.

predacious foes of insects are worthy of as high consideration as parasitic ones is afforded by the instance of the extermination, successively, by the ladybird, *Vedalia cardinalis,* of the cottony cushion scale in California, of the fluted scale in South Africa, and of a congeneric scale insect in the gardens of Alexandria, Egypt. Lady-birds of the genus *Hippodamia* are used with great success in the control of injurious aphides in California. These are among the greatest successes that have been obtained in biological control and they have involved the use of predators, not parasites.

The statement by Professor Strickland, that "provided man does not upset the relationships between any plant-feeding insect and its parasites, the average population of that plant-feeding insect can never vary very extensively over periods of more than a few years," is applicable to almost any opposed relationship between organisms throughout the whole range of nature. It is not peculiar to insects and their parasites; the statement might read insects and their bird enemies, fishes and fish-eaters, insects and spiders, in fact almost any similar case and be equally true. Perusal of Dr. S. A. Forbes' paper "On Some Interactions of Organisms"[2] is recommended in this connection.

Again our author says, "We can not but conclude . . . that the annual destruction of plant-feeding insects by birds has no appreciable effect upon their ultimate abundance." This statement is just as applicable to every natural check: the word "parasites" can be substituted for birds in this statement and it will be just as true. The ultimate abundance is on the average the same, as our author himself repeatedly states in this paper.

Our author finally admits that birds eat parasitic as well as plant-feeding insects, thus undermining the highly artificial arguments he builds up on the premises of selective destruction of phytophagous insects by birds. As a matter of fact, birds as a whole tend to apply indiscriminate pressure on the insect race, cutting them down in proportion to their numbers, work which in its indiscriminacy parallels that of all factors of natural control combined, which tends to preserve the balance of nature, so called, and is therefore good.

Professor Strickland quotes from Rondani that "the policing of fields can not be entrusted to birds because they are unreliable and kill the guilty with the innocent." It is almost inconceivable how entomologists can make such statements as this and not see the implied condemnation of their own most effective methods of combating insects. Stomach poisons result in the death of any parasites contained in the bodies of hosts feeding upon them, contact poisons kill friend and foe alike, fumigation with poisonous gases is indiscriminate in its effect. Nevertheless, these are the principal weapons of the economic entomologist. They do good, are effective in securing the degree of control we need for crop production, have long been used and will continue to be used. Their effectiveness proves that a general reduction in the number of insects, useful along with the harmful, has a satisfactory net result, and is in effect a strong endorsement of the utility of birds whose combined activities against insects tend to be indiscriminate. One eminent entomologist who sees the truth in this respect, Paul Marchal, says: "However useful the parasites may be, the fear of destroying them ought never to prevent the taking of all measures having for their object the direct destruction of harmful insects"; and with regard to birds, "the protection of in-

[2] Bull. Ill. State Lab. Nat. Hist., I, No. 3, 1880.

sectivorous birds appears to us not at all susceptible of thwarting the beneficial action of useful insects."[3]

Professor Strickland asks the question, "Can birds hold injurious insects in check?" and his answer is, "It is improbable that in the case of the vast majority of plant-feeding insects, birds are a factor of much importance in reducing their population." In this connection let us quote two sentences from earlier portions of his paper: "We all know, however, that, with comparatively few exceptions, each of our numerous kinds of insects is present in approximately the same numbers from year to year." . . . The relative number of eggs that are laid by different species of insects has surprisingly little effect upon their annual abundance," and there are other expressions certifying to the normal year to year stability in numbers of the insect population. These statements mean that no agency permanently reduces the population, and place parasites as well as other checks on insect abundance in the same category Professor Strickland attempts to assign exclusively to birds. As a matter of fact, insect control aside from that applied by man is due to a combination of all inimical factors—unfavorable manifestations of climate, activities of predators, and parasites, of both the animal and plant worlds, and failures due to constitutional defects in the insects themselves—in a word to the whole environmental complex. Little is gained by discussion of the relative value of the various biological factors, while much risk of error is incurred.

With regard to birds, it may be said that economic ornithologists gauge the usefulness of birds more on their general tendencies than on specific activities. These scientists do not make exaggerated claims of the sort alleged by Professor Strickland. They recognize that the most useful function of birds lies in their constant cutting down of the numbers of insects in general, and not in their more spectacular services in the presence of insect outbreaks.[4]

At the same time we need not hesitate to point out certain features of insect control by birds that entitle them to special appreciation. Birds have the advantage of stopping the feeding of an insect victim at once; parasitized, the insect may continue feeding and possibly consume more than the normal amount of food. Birds are not so much affected by climatic factors as are parasites and do not require two or three years as do parasites after every setback to again apply effective pressure on the numbers of their prey. When harmful insects are introduced into the country, it may be years before parasites become adapted to them, or we may be compelled to import parasites; birds can and usually do feed upon them from the first. Birds are a mobile force against insects and gather at the scene of an insect outbreak. If the latter is local a bird population several times the normal for the area may assemble and feed upon the insect to a much higher than usual extent, and there are numerous records of birds actually extirpating such local infestations.[5] No one claims that birds can control widespread outbreaks of insect pests nor do we observe parasites so doing.

However, there is no necessity for belittling the services of either of the two great classes of pest destroyers. Both consume a certain proportion of insects directly injurious to man, and it is more than likely that either would be hind-

[3] Ann. Inst. Nat. Agron., 2e Ser., T. VI, 1907, pp. 298–299.

[4] Beal F. E. L., "The Relations between Birds and Insects," Yearbook, U. S. Department of Agriculture, (1908). 1909, pp. 343–350.

[5] McAtee, W. L., "The Rôle of Vertebrates in the Control of Insect Pests," Smithsonian Rep. (1925) 1926, pp. 415–437.

ered rather than helped by the absence of the other. Everything, indeed, points to the conclusion that from the standpoint of man's welfare the loss of either class would irreparably disturb the balance. What has been said by a noted entomologist concerning parasites, namely, that the presence of both parasites and hosts, continuing through thousands of years to the present, implies that an equilibrium is maintained, enabling each to live, is just as true of predacious enemies, both in relation to parasites and to their common prey. There can be no doubt that, even under the greatly changed conditions induced by man, the inter-actions of these classes tend directly toward the establishment and maintenance of a balance. It is probable that this balance can be secured at a lower level in regard to number of individuals only by direct reduction of the injurious species by man, coupled with the best possible protection of both their predatory and parasitic enemies.

Birds are one of the natural forces regulating the numbers of insects, and it takes all of them combined to do the job. In fact, even all of them together can not do it as we should like, and it should not be forgotten that, regardless of birds, parasites or other natural checks, it will as a rule be necessary under the artificial conditions he has created, for man to combat insects directly in order to secure the degree of control necessary to commercial success.

SPECIALIZATIONS GOVERNING MUSICAL EXPRESSION AMONG INSECTS

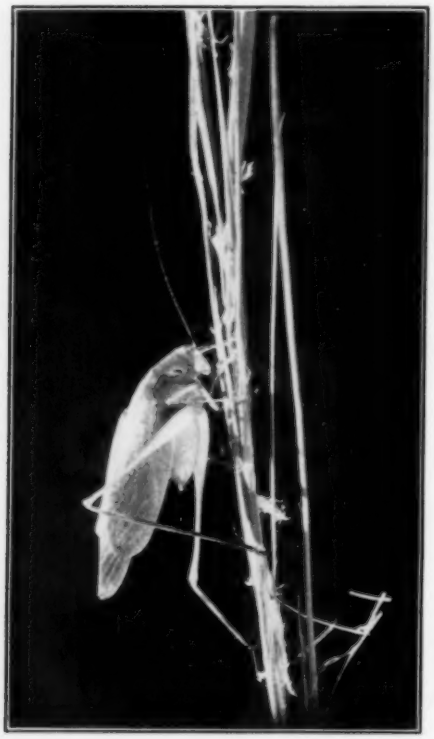
By H. A. ALLARD

U. S. DEPARTMENT OF AGRICULTURE

AMONG the birds it is well known that musical expression has reached a high degree of development, as attested by the masterly singing of our own thrushes, the wood thrush, the veery and the hermit thrush. The birds, however, have specialized in vocal music. Nature has made them the spontaneous vocalists of earth whom none excel. The distinctive instrumentalists of earth are our musical insects, and they have learned to do their humble part well. In the sense of singing through the buccal cavity, no insect possesses a voice. The cicadas or harvest flies, so called, sing within special cavities of their bodies and to this extent come nearer being true vocalists than our crickets and katydids. In the music boxes of the cicadas thin chitinous membranes are at will set in rapid motion by a very powerful and efficient musculature. Not having lungs and throat adapted to vocal singing, the majority of our musical insects have developed external frictional structures wherever contiguous surfaces naturally approach each other and can be rubbed together at will. When we consider all the insects as a class, scarcely any part of the body has been overlooked. It would seem that every movable chitinous surface of the external insect body capable of rubbing upon another part is potentially a musical organ. Strange it is that in some great groups remodelling and sculpturing to produce file-vein and scraper or plectrum has been so consistently followed. It is incomprehensible that this specialization should arise unconsciously, spontaneously as the refinements of crystalline structures in inanimate matter appear to arise: it is as equally incomprehensible to see how the consciousness of life should evolve and shape its trend. No philosophy of life explains it but it is there, and it appears to be as deep a riddle as life itself.

Marvelous specializations for making sounds have evolved among the beetles, and have arisen on nearly every part of the body where two adjacent surfaces can be brought together. They have arisen upon the head, the mandibles, the pronotum, the mesothorax, the fore legs, the middle legs, the abdominal segments, the elytra or wing-covers. It would appear that in practically all types of frictional stridulation the typical structure is concerned with a file-vein and scraper to be drawn across its teeth. However, many simpler structures apparently less refined may also be found as merely roughened surfaces, ridged or tuberculate. The mysterious forces of life appear to be not always content with mere simplicity, and once a tendency arises, specialization and elaboration may be expected to unfold, to almost any degree of refinement.

As yet, characteristic of the beetles and possibly some of the ants alone, so far as known, it would seem remarkable tendencies have been shown. We have spoken of the simple file-vein, which corresponds to the teeth of a comb, as a sound-producer. It is evident that the teeth of this microscopic file or rasp are the rigid strings, so to speak, of this natural insect violin or mandolin. Some beetles, strangely enough, have been generously equipped with two file-veins and



UHLER'S KATYDID (*Amblycorypha uhleri*) MALE. THIS LITTLE KATYDID HAS A VARIETY OF LISPING NOTES. ABOUT NATURAL SIZE.

even with additional accessory musical structures in some instances, so that veritably are they musical adepts on more than one instrument. It is a marvelous elaboration among the lowly insects, but that is not all. Nature with the organic magic of her cosmic touch has elaborated the simple file-veins in a masterly way. She has made them with fine teeth in one part and coarse teeth in another. On the file-veins of a few beetles she has even produced three sets of teeth, coarse, medium and fine. What does this mean? It probably means that at least three distinct sounds may be produced at will, with variations of loudness and pitch or shrillness. Here would it seem the insects are breaking away from the monotony of a single note, and have in mind the production of several notes, or perchance a primitive scale like the birds with their vocal chords. There is something deep and significant in these trends and specializations of the organism playing with sound, seizing upon it to make it a part of its conscious experience at last.

While the beetles show many elaborations indicative of sound sensitization and sound-consciousness, very little is known of the actual sounds they produce, because they are too far removed from the everyday experiences of the human ear to receive much attention. For this reason not much poetry is going to arise soon glorifying the singing of the beetles. Fortunately we have another order of insects which are instrumental musicians of the highest stamp, the Orthoptera, including all our musical grasshoppers, katydids and crickets. Many of these are large enough to be heard in everyday life, and many of them have with merit sung their way close to our hearts and moods, so that much of our poetry savors of their presence. This is well, for who does not love the chirping and purring of our crickets?

Profoundly musical are these dainty creatures, perhaps more truly musicians from the pure love of sound for its sake than the beetles themselves. I do not call an insect a disinterested musician that sings merely to call its female to it, or because it wishes to terrify something, as we have explained it rather glibly, but because it sings for no other reason than that it loves sound and the pleasures of sounds, as do we humans. The utility theory, so glibly invoked by Darwin and others to explain all the musical moods of insects, will not stand the test of close scrutiny. There are other reasons back of the mood than the enticements of sex, etc., just as among the birds and among humans. There is just as good reason to believe insects find pleasure in their sounds as do humans

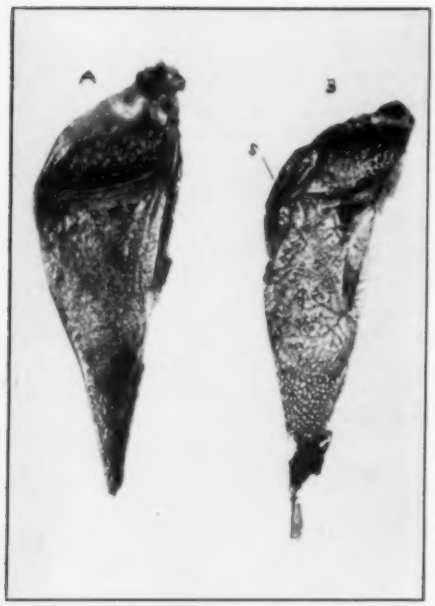
in theirs. Simple as the sounds of insects appear, oftentimes little more than rasp and rhythm, one must not forget that the beginnings of man's primitive music were scarcely more than sound and rhythm; and, let me add, oftentimes not much better is much of our modern music to-day.

The fundamental principle of a file-vein and scraper with few exceptions is found among all the grasshoppers, katydids and crickets. It appears to be the universal principle of musical evolution in the development of nearly all insect instrumentalists, except the cicadas, yet what else could the living impulses well seize upon to modify in the direction of instrumental music? The forces of life seem to have well recognized this, and the file-vein is the type of all frictional music. It may and does appear on a variety of structures, being upon the hind legs or upon heavy veins of the wing-covers in our own true grasshoppers. In our own commoner katydids and crickets, however, the position is quite consistently at the base of the wing-covers alone.

So far as known, the crickets and katydids have not given especial attention to modifications of different portions of the file-vein, as have the beetles. Yet as I shall show, specializations of the musical impulse and touch and time-relations have been profoundly elaborated just as among the birds with their vocal music.

First we may consider the matter of musical tone or pitch among insect musicians. Almost without exception, the grasshoppers and katydids merely rasp or scrape out noise of one quality or another, loud, rasping or soft, silken, lisping. At no time is it characterized by musical pitch or tone. The crickets with the same type of file-vein have somehow gone immeasurably beyond the katydids by developing true tonal music or pitch, and they have done this as a great group. It is a marvelous forward step in the evolution of genuine music, and to be genuine music for the human ear, tonal-quality must come into the component sounds. Who shall say there has not been an upward trend here consciously or unconsciously, organically or inorganically, as we please to regard it? It is a mistake, however, to think the human ear is the only criterion of music in the universe. The mere noise of the katydids may have the fundamental elements of music in it as truly as the tonal sounds of the crickets. To the katydid ear analysis of their own sounds may be as acute as our ears for our own more musical tones. As a matter of fact my own ear can detect wide variations of quality in the clicks struck off by the larger angular-winged katydid in using the single teeth of its file-vein.

This is the first point in our analysis of the musical impulses of insects. We will now go back to the katydids, with their strident lisps and rasps, and see what they have done with simple file-veins and scrapers in evolving the formalisms of music. There was a time when I regarded the abilities of the katydids as of a simpler, lower order of specialization than the crickets, because the crickets had evolved tonal quality, and the katydids only noise, sound. I have been led to change my mind. It is evident that specialization may proceed in more than one direction. In the case of the beetles, elaborations and refinements of the teeth of the file-vein have taken place: In the case of the crickets the great forward step has been the acquirement of musical pitch. In the case of the katydids evolution has been in the direction of a better control or manipulation of the musical structures and a consequent specialization in the direction of variety of notes. In this behavior the katydids have gone far ahead of the crickets in spite of their momentous tonal accomplishments. It was a



MUSICAL ORGANS OF THE LARGER ANGULAR-WINGED KATYDID (*Microcentrum rhombifolium*). A. FILE-VEIN ON UNDER SURFACE OF UPPER TEGMEN. B. SCRAPER—A CHITINOUS RIDGE AT S, SITUATED AS THE UPPER EDGE OF THE LOWER TEGMEN. MAGNIFIED ABOUT 10 TIMES.

wonderful step to leave mere noise behind and seize upon tone. Yet if the crickets had kept pace with the katydids in the evolution of a better manipulation, they would now have been playing simple tunes almost, like some of the birds with their vocal art.

There is every degree of musical expression among the katydids. Some of the cone-headed katydids (*Neoconocephalus*) merely set their wings humming in a continuous buzz of monotonous sound, perhaps the simplest musical expression, for not even rhythm is involved. The next step is to break up this simple monotone into rhythmic intervals, and some cone-headed katydids do just this. They do it with an astounding uniformity—slower with cool temperatures, faster with high temperatures. These rhythmic rasps or beats are a substantial advance in music evolution, it would seem. They mark the earliest beginnings of definite musical expression. Among men as well is this true, for primitive men cared as much for the pure rhythmic beat as for anything else. Burton, speaking of the music of African savages, said they would sit for hours at night chanting with an untiring mood, a ceaseless repetition of a few notes or lines. Let me add that our musical insects as well as men have an inherent ear for simple rhythm. Gurney has said "The fact of the love of mere rhythm and repetition among uncivilized people seems nearly universal." But this love of simple rhythm goes back even to the crickets themselves: it is not a characteristic of the lives of men alone.

Such were the beginnings of man's music, and such is much of our insect music to-day, an irrepressible mood for the mere rhythmic repetition of sound. It would be a real step forward to break away from this almost inanimate mechanical rhythm, and some of the katydids have done this. The big meadow katydids of the genus Orchelimum have introduced variety into their mechanical "songs." They have done it by varying the notes and phrases in more or less definite ways, establishing new time-relations and sequences of sound. The typical Orchelimum song begins with a series of short staccato notes, then runs off into a long lisping monotone. It may be represented thus: *zip-zip-zip-zip-zeeeeeeeeeeeee*, *zip-zip*-pause, *zip-zip-zip-zip-zeeeeeeeeeeee*, *zip*. This song has very much of the stamp of the grasshopper sparrow's simpler song or lisping monotone. It is evident that it has more variety and complex time-relations than the simple rhythmic *zip-zip-zip-zip* repeated for long hours by some cone-headed katydids.

One of the most remarkable songs is that of the little Uhler's katydid (*Amblycorypha uhleri*) common in the Washington region. There is even more

variation in the complete expressions of these katydids than in the songs of the Orchelimums. These complexities denote specializations in the direction of variety. Some weird evolving principle is at work upon their songs, breaking up the basic, eternal rhythm into something finer, more prolonged, more varied, analogous to the refinements and specializations shown by the finer singers among the birds. Strange to say, these specializations have gone much farther among the noise-rasping katydids than among the tone-loving crickets, for as yet the latter still cling to the simple monotone or the more or less regular, rhythmic chirp. In not one instance, at least among our eastern crickets, have they shown the elaborations toward new complexities of expression characteristic of some of the katydids. The little Uhler's katydid begins its song with a prolonged, soft, lisping sound, produced by a rapid shuffling of the wings. This soon runs into a succession of short staccato lisps *zip-itsip-itsip-itsip-itsip*—and ends with a rapid shuffling sound, several times repeated—*sh-sh-sh-sh*. The entire song may be expressed thus: *s-s-s-s-s-s-s-sip-itsip-itsip-itsip-itsip-sh-sh-sh-sh——sh-sh-sh-sh——sh - sh - sh - sh*. Sometimes additional staccato notes, *tip-tip-tip-tip,* are added to the final lisping phrases.

This is a remarkable elaboration as compared with the brief, monotonous, recurring zips of a cone-headed katydid or the simple chirps of a cricket. It is evident that much more can yet be done with a simple file-vein with teeth, operated upon by a plectrum or scraper. There are many teeth on the file-vein depending upon the species of insect-musician. Some may have around fifty to sixty teeth; others may have one hundred to several hundreds. In practically all instances, the scraper is drawn entirely across this vein to produce one rasp or backwards and forwards several times to produce a single chirp or rasp. However, there are additional possibilities here, one being the selection of one or more teeth to produce a single note or tone. Remarkable as it may seem, one katydid, the larger angular-winged katydid (*Microcentrum rhombifolium*), has somehow learned this potentiality and has specialized upon it in a unique way. This katydid has two distinct notes, one a loud, keen zip, made by opening the wing-covers and bringing them suddenly together. In this movement the scraper passes over the entire file-vein as one would draw a knife-blade smartly over all the teeth of a comb in one quick brief draw. The other "song," perhaps the only true "song" of the species, shows a remarkable manipulation of the scraper over the file-vein. The upper edges of the wing-covers are separated as far as possible, perhaps three sixteenths of an

LARGE MEADOW KATYDID (*Orchelimum vulgare*) MALE. A SINGER OF THE HOT AUGUST DAYS. ABOUT NATURAL SIZE.

LARGER ANGULAR-WINGED KATYDID (*Microcentrum rhombifolium*) MALE. FINEST OF ALL OUR KATYDIDS. IT HAS LEARNED A MARVELOUS TECHNIQUE WITH ITS ALMOST MICROSCOPIC CHITIN XYLOPHONE.

inch, then allowed to close with such a nicety of judgment that the scraper, striking only one or more teeth of the file-vein at a time, produces a series of from twenty to thirty or more loud leisurely clicks, becoming more rapid toward the close until the wing-covers have been brought entirely together. So far as the writer's observations go no other katydid and none of our crickets has acquired this nicety of judgment and touch in their musical expressions. The file-vein of this katydid possesses about fifty-five to sixty teeth if one includes every reduced tooth at each end, or perhaps not more than forty to forty-five well-developed teeth. If thirty to thirty-five notes were produced in this single closing operation of the wing-covers, it is evident that not more than one or two teeth could be involved to produce each click. This to my mind represents a remarkable understanding and manipulation of the simple mechanical features of the musical file-vein. It is the first evidence which we have that perhaps the musical insects are working toward simple melody, as the birds have done. As a matter of fact, the separate clicks of this katydid show marked variations in volume and pitch to the trained ear, even though it is not a sound with musical pitch, such as human ears appreciate. If the crickets have made a momentous step forward with the production of musical tones in place of rasping noise, this katydid has attained a remarkable specialization and skill in technique dealing with the primitive rasp. Should now the crickets attain this same technique with their file-veins, we would have a veritable series of musical tones capable of enough variation in pitch by further elaboration to produce the simple melody, and quite as efficiently as the birds have done with their vocal chords.

With the musical impulses of life in the field of instrumentalism specializing upon the file-vein, the character of the file-vein and its teeth and the matter of technique in using this are the two potentialities alone which would be involved. It is evident that the insects are showing unmistakable trends in both directions. Some of the beetles and perhaps the ants have gone far in elaborating the structures of the file-vein; some of the katydids have hit upon a highly specialized and skilful technique. Finally, the crickets have hit upon tonality such as men pronounce good from the point of view of their own musical sensibilities. These are the indubitable facts. What they mean we know not, nor never will, perchance. However, it is plain that sound-sensitivity is one of the elemental characteristics of life as truly as light sensitivity. Men merely share the same musical tendencies with countless other forms of organic expression.

The crickets and the katydids are the great insect instrumentalists of earth, as much impressed with sound rhythms as are we and even with tonality, it would

seem. Perchance they are but passing along the mysterious musical ways of men in some weird, organic, cosmic trend toward a fuller appreciation of sound, involving pleasurable sequences of tone, time-relations and tonal combinations which we call music. Our own musical specializations rest upon the same elemental foundations that the insects and the birds make use of. Rhythm is as much within their mood as within ours. The file-vein of the cricket is but a microscopic many-stringed mandolin, so to speak, or perhaps more correctly speaking a xylophone with parallel resonant chitin bars comparable to the resonant pieces of wood of different lengths arranged to produce the tones of the xylophone. The xylophones of men are but larger file-veins which they make but which will not grow naturally upon the integuments of their backs or legs. It would be just as easy for the deep cosmic intelligences of life, of which we know nothing, to fashion the simple file-vein or natural microscopic xylophone of the cricket into one with a scale of simple tones as for the birds to do it with their vocal chords. If our tales of evolution are really true, the birds have done it, and the hermit thrush is an outstanding virtuoso of this evolution from mere lowly reptiles.

The birds have gone far in their musical evolution, but upon the same basic principles observed to-day by our musical insects. The primitive scale is within the bird's soul. F. Schuyler Mathews has written: "But of serene, exultant melody in the music of the birds there is plenty; the plainest evidence of it is in the songs of the thrushes, and we have convincing proof that their music is built upon definite, primitive scales—scales which the birds used eons of years before man did."

There is another feature of insect music, not at all understood but resting upon the basic foundations of their internal sense of rhythm. I speak of the synchronous rhythm characteristic of the singing of certain chirping tree crickets, the snowy tree-cricket (*Oecanthus niveus*). Many crickets sing with regularly delivered notes; others do not. They sing with the mood of rhythm in their souls. More than this, some species, singing in company, sooner or later prefer to adopt the same time relations and chirp in unison. Now do we have a marvelous group synchronism, each chirp the "rhythmic beat" of the multitude. It is a keeping time and step and nothing more. It is no figment of the imagination, but a fact observed by men of science and reported by Fulton and others.

What it really means we do not know, but these famous snowy tree-crickets strive to keep time, and appear to sing more at their ease when they can do so,

SNOWY TREE CRICKET (*Oecanthus nivcus*) MALE. THE POET'S CRICKET, WITH A LOVE OF RHYTHM IN ITS SOUL EVEN AS MUCH AS MEN.

based on some peculiar law of internal rhythm governing their musical makeup. I have made some studies of this question, and have found that a cricket, chirping at a certain rate per minute, will actually hurry his notes or change their rate to adopt a slightly different rate of mimic chirp to which I subjected him. All these features of musical expression are deep-seated elemental moods of life, governing not alone the music of insects, but the seemingly more conscious musical specializations of men.

It is strange that although the birds as a class are vocalists, even they have turned to various forms of instrumentalism, as well as the insects. The ruffed grouse beats a soft, thrumming tattoo upon the air; the snipe has learned to bleat with its tail-feathers in a rapid descending flight, and the night hawk has learned to twang a boom loudly upon the atmosphere with its wing pinions in a terrific far-flung drop to earth. Even a Turkestan lizard has learned to produce a cricket-like shrilling with certain modified scales or plates upon its tail.

These all represent the same strange unaccountable strivings of life after ways of producing sound, because somehow sound affects the organism strangely, weirdly and seems necessary to its well-being and pleasures of existence.

The organism, it would seem, is as sensitive to the ubiquitous sound-waves as to light-waves, and in the case of the katydids and crickets would analyze them and wear them upon their backs, as some analyze and wear the light upon their integuments in varied patterns and colorations. There are strange organic analogies here between the responses of life to sound-waves and to light-waves. Those fundamental organic moods, responding to the sound-waves so aptly and adroitly, seem as spontaneous and as unconsciously originated and regulated oftentimes, as the external integuments to the disposition of the light falling upon them. Specialization somehow subtly takes hold of life and all the potentialities of life, till the organism feels the growing consciousness of its refinements, and henceforth consciously directed behavior seems to come in. There is much to be learned concerning the specializations of the musical interests. As yet it is a great, almost untouched department of science. Although musical insects occur in practically all parts of the world where plant life is found, unfortunately very little is known of the musical behavior of this great group of insects. It can not be considered a trivial and unworthy subject of scientific study, but one as broad and as complex as the vocal singing of birds. There are questions of fundamental importance in the matter that deserve to be examined, concerning the insect's ear for sound, for rhythm, synchronism, tonality, etc. It is quite probable that a complete survey of all the musical tendencies and behavior of the musical and sound-producing insects of the world would throw much light upon the fundamental musical concepts and tendencies of man himself, for common irrepressible laws seem to govern the musical moods of their lives.

THE PROGRESS OF SCIENCE

HIDEYO NOGUCHI

1876–1928

In 1900 Dr. Hideyo Noguchi joined the staff of the department of pathology at the University of Pennsylvania as a volunteer. His interest in bacteriology had already manifested itself, for in 1898, very soon after his graduation from the Tokyo Medical College, he became assistant at the Government Institute of Infectious Diseases, of which Professor Kitasato was the director.

Dr. Noguchi's coming to Philadelphia was quite fortuitous. The writer stopped in Japan on his way to Manila, and chance threw him and Dr. Noguchi together. Noguchi remained at the University of Pennsylvania for four years, and then accompanied him to New York, to become one of the small group composing the original scientific staff of the Rockefeller Institute.

It was during the Philadelphia period that Noguchi's exceptional gifts as an investigator manifested themselves. The investigation of the venoms, pursued from the standpoint of the newer knowledge of toxins and antitoxins which Ehrlich's brilliant theoretical generalizations had done so much to increase, yielded a rich booty. The choice of the venoms for study was in turn influenced by Dr. Weir Mitchell's earlier important investigations on snake venoms. Dr. Mitchell was instrumental in supporting the undertaking, at first personally and later through the interest he aroused in the National Academy of Sciences and the Carnegie Institution of Washington.

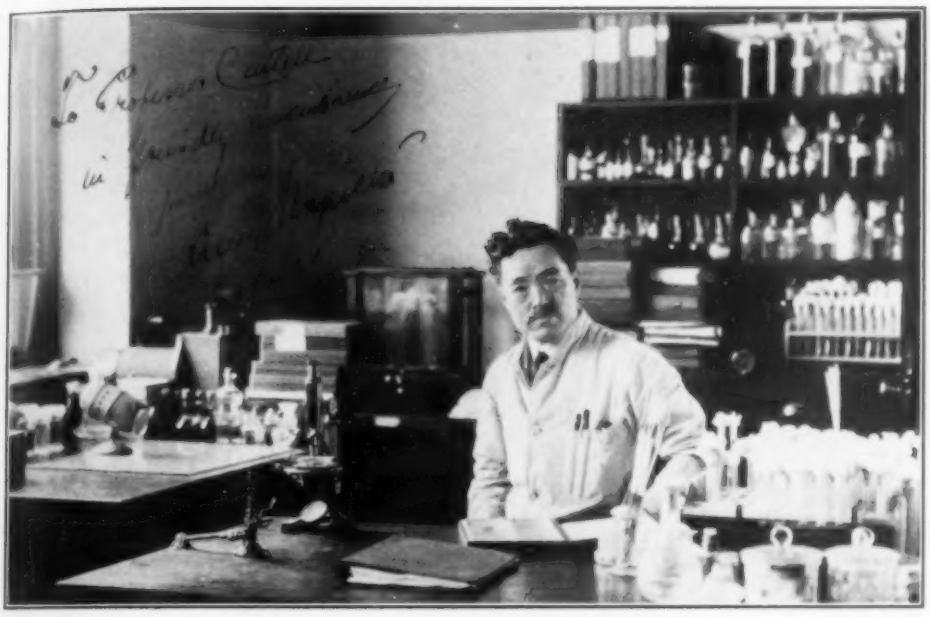
At the Rockefeller Institute, Noguchi devoted himself in particular to the investigation of unusual microorganisms and diseases of unknown origin which they induced. His rewarding studies on spirochetae, a number of which he cultivated artificially for the first time, form a model piece of bacteriological research. Among those obtained in pure culture is *Treponema pallidum*, the incitant of syphilis. Others include the spiral microorganism of relapsing fever and African tick fever. Besides these he cultivated many mouth and other spirals for the first time.

We owe to Noguchi the finding of the syphilis spiral in the brain of paretics, a demonstration which lifted this serious disease from an inferential to an established position in the list of syphilitic infections. This finding was a feat of observational acumen comparable with Schaudinn's detection of the pallidum in the lesions of syphilis.

In 1915, profiting by his work on the spirochetae, Noguchi purified vaccine virus from associated bacteria by cultivating it in the tissues of rabbits. This method of securing bacteria-free virus for vaccinating human beings is now being widely employed.

In 1918 Noguchi made the first of four expeditions to South America to investigate yellow fever. He accompanied the commission sent by the International Health Board of the Rockefeller Foundation to Guayaquil and isolated *Leptospira icteroides* from six of twenty-seven cases of yellow fever. On subsequent expeditions to Mexico, Peru and Brazil he cultivated the same organisms from cases of yellow fever in those countries.

Recently Noguchi isolated *Bartonella bacilliformis* from cases of Carrion's disease (oroya fever) and verruga peruana, and thus established the relationship of the two conditions previously controverted. By employing cultures for inoculation into *Macacus rhesus* he repro-



HIDEYO NOGUCHI
IN HIS LABORATORY AT THE ROCKEFELLER INSTITUTE

duced the two pathological conditions representative of the two natural diseases.

In 1926 Noguchi accomplished the cultivation of a new bacterium from the eyes of American Indians, which on inoculation into the conjunctivae of *Macacus rhesus* and chimpanzees reproduced the lesions of trachoma as they exist in human beings. A monograph describing in detail the work on trachoma was completed just before he sailed for Africa; it is in press and will soon be published.

Noguchi died of yellow fever at Accra, on the Gold Coast, West Africa, on May 21. The expedition to Africa was undertaken for the Rockefeller Foundation, because the results of his investigations of yellow fever in South America proved inapplicable to the disease as it exists in Africa. His African investigations were virtually completed when he was himself stricken with the disease. The results of his studies will not be lost, as they are described in letters, and his notes and materials have been carefully preserved.

Noguchi was an international figure, much respected and beloved. His premature death is a great catastrophe, and messages of sorrow and sympathy have come from many lands. His name is to be associated with the great investigators who founded bacteriology and have placed it so securely among the experimental sciences.

SIMON FLEXNER

Edgar F. Smith
5/25/1926

EDGAR FAHS SMITH

1854–1928

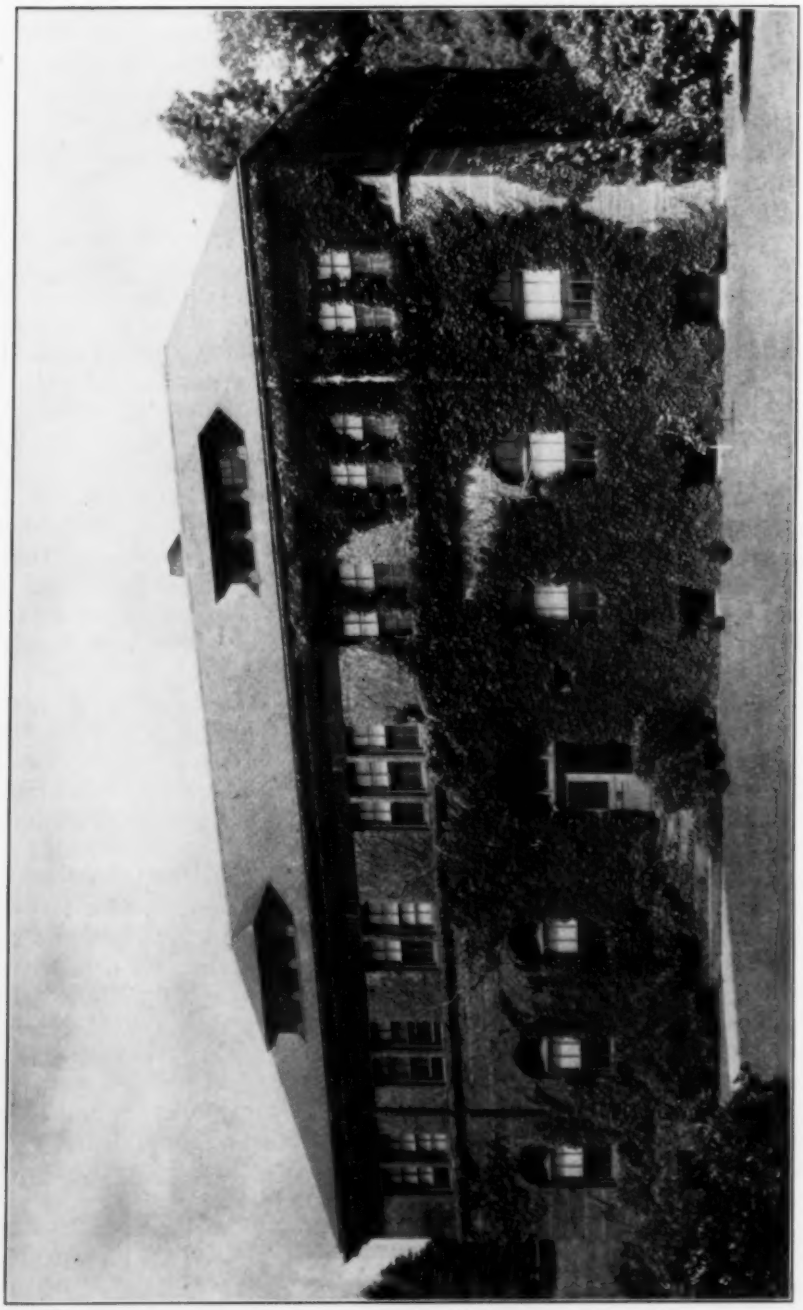
CHEMISTRY in America has suffered an irreparable loss through the death of Edgar Fahs Smith, which occurred on May 3 in the University of Pennsylvania Hospital. Even outside of his chosen profession and beyond the limits of his native country the news of his demise will occasion keen regrets, for Dr. Smith enjoyed an international reputation not only as a chemist, but as an administrator and a historian. The respect felt for his scholarly ability in many fields was accentuated by the universal affection inspired by his modest and kindly personality. He was indeed a true gentleman, in the oldest and best sense of the word.

Born at York, Pennsylvania, where his ancestors settled several generations ago, on May 23, 1856, Dr. Smith successfully resisted his father's plans for a business career, and resolved to study medicine. He prepared for college at the York County Academy and entered the junior class of Pennsylvania College, Gettysburg, in 1872. Before he graduated in 1874 with the degree of bachelor of science, his work in chemistry had been of such promise that his teacher, Dr. S. P. Sadtler, encouraged him to go to Germany and continue his studies there. Acting on this advice, Dr. Smith worked for two years at Göttingen, where Wöhler was one of his professors, and gained the degree of Ph.D. Returning to the United States in 1876, he became an assistant in analytical chemistry to Professor F. A. Genthe, of the University of Pennsylvania.

At this institution, except for brief intervals at Muhlenberg College, Allentown, Pa., and at Wittenberg College, Springfield, Ohio, Dr. Smith spent the rest of his active career until his retirement in 1920. He became in 1888 professor of analytical chemistry, in 1892 head of the department of chemistry, in 1898 vice-provost and in 1911 provost of the university. During his forty-four years of teaching and administrative work, he gained the title of "the best beloved college professor in America" and impressed his spirit and personality upon more than fifty thousand students.

Honors in abundance came to Dr. Smith for his unselfish labors. Besides more than twenty degrees from different universities, he was awarded the Elliott Cresson medal of the Franklin Institute, the Chandler medal of Columbia University and the Priestley medal of the American Chemical Society. He served thrice as president of the American Chemical Society, in 1895, 1921 and 1922. These distinctions were not accompanied by corresponding material prosperity, for which Dr. Smith cared little. Although he was a public servant on innumerable boards and committees in local and state interests, he consistently declined public honors and advancement, engaging in philanthropy to the limit of his resources, secretly supporting poor students and contributing to many charities. On his retirement he applied to the Carnegie Foundation for a pension, declaring that he was penniless, and of his career as a teacher he said: "That is wonderful but unremunerative work. And one does not grow rich, either, from writing text-books on chemistry."

An indefatigable research worker in the subjects of mineralogy, electrochemistry and analytical chemistry, Dr. Smith published more than two hundred original papers. His investigations upon the rarer metals have been of industrial as well as academic significance. He wrote, translated and edited a large number of text-books. During his later years he became particularly interested in the early development of chemistry in America, and his historical studies in this field are of



THE HEADQUARTERS OF THE ARNOLD ARBORETUM

notable literary merit as well as of great scientific value.

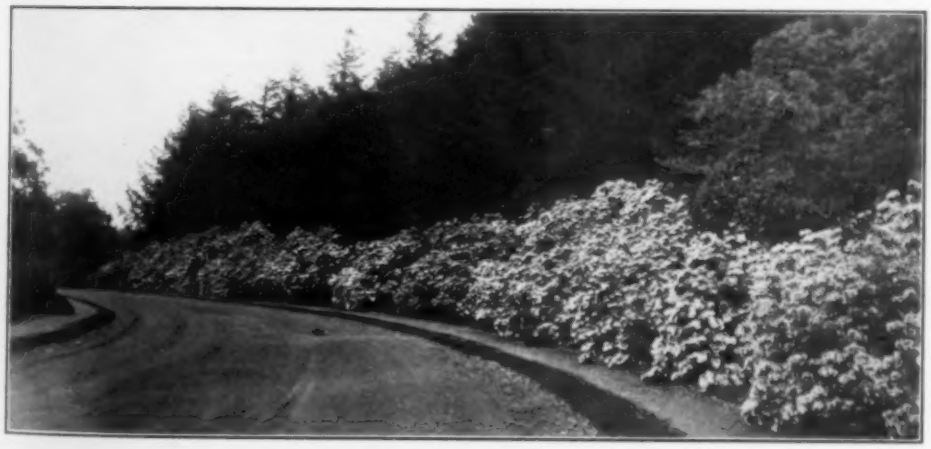
In 1926 a statue of Edgar Fahs Smith was erected near the Harrison Chemical Laboratory of the University of Pennsylvania. In the hearts of his colleagues, however, he needs no more permanent memorial than that which his own sterling qualities gained for him. At a dinner recently given in his honor at the Chemists' Club in New York City, he was introduced as follows: "Edgar Fahs Smith, gentleman, chemist, great teacher, historian, true philosopher and sincere friend. Few men have so richly deserved at once the esteem in which Dr. Smith's professional achievements are held and the affectionate respect his character and personality have won."

Dr. Smith practically died in harness, since one of his last acts was to attend the spring meeting of the American Chemical Society at St. Louis. On the return journey, he contracted a chill, which developed into pneumonia. He is survived by his wife, Margie A. Gruel, of Gettysburg, whose tender care and companionship brightened his life for nearly fifty years and to whom the deepest sympathy of all his friends is extended in her bereavement.

JAMES KENDALL

THE ARNOLD ARBORETUM OF HARVARD UNIVERSITY

THE Arnold Arboretum of Harvard University was established in 1872 for the study and cultivation of all the woody plants capable of withstanding the climate of Massachusetts. Its original endowment was one hundred thousand dollars, left for this purpose by James Arnold, a merchant of New Bedford, Massachusetts. For the purpose of carrying out this trust Harvard University set aside 125 acres of land known as the Bussey Farm. In 1873 Charles S. Sargent was appointed director, a position he held until his death on March 22, 1927. By an arrangement with the city of Boston, who maintain the roads as part of the park system, the Arnold Arboretum is assured of its present site for a thousand years and is tax free. It is policed by the city of Boston and is open to the public from sunrise to sunset every day in the year. When Professor Sargent died he had increased the endowment of the Arnold Arboretum to over a million dollars and the area to about 260 acres, wherein are now grow-



AN INTERIOR VIEW

ing more than six thousand five hundred species and varieties of tree, shrub and vine. To commemorate the life work of Professor C. S. Sargent and to still further increase the services of the Arnold Arboretum a Charles Sprague Sargent Memorial Endowment Fund for a million dollars was undertaken and so far more than nine hundred thousand has been collected. On the death of Professor C. S. Sargent, Professor Oakes Ames was appointed supervisor and Mr. E. H. Wilson, who had been assistant director, was made keeper.

Among the changes that have taken place, a new and larger greenhouse and nursery for the Arboretum is being erected on the South Street side of the Arboretum on the rising ground of the Bussey Institution. A new feature of the greenhouse will be a laboratory fully equipped for research in plant pathology and genetics. The greenhouse will be about fifty feet long and will have, also, a workroom for potting, and pits for the growth of woody plants. The nursery, a few feet away, will cover about three acres of land.

Professor Oakes Ames has stated that:

> A most important part of the Arboretum work —hybridization and the study of living conditions and diseases of plants with a view to improving their inherent qualities—has never been attempted before because the necessary facilities were lacking. Up to now its main work has been the assembling of woody plants and trees from all parts of the world, identifying, classifying, propagating them and exchanging them with other arboreta and nurseries, and building up a matchless library and an outstanding herbarium. For lack of funds the Arboretum has thus been limping along on one leg, although limping very efficiently because of Professor Sargent's able direction.

With part of the income from the million dollar endowment fund now being sought, it is proposed to establish two departments of research so that students and dendrologists may take advantage of the wealth of material that has been amassed during the past half century. It is hoped that the economic quality of native trees will be improved, just as scientists have improved flowers and fruits. By cross-fertilization of different varieties and species of forest trees it is expected that great improvement in the economic value of woods will result. Professor Ames explained:

> We want to make the Arboretum a world center not only of systematic dendrology, but of dendrology as a whole. The proximity of the new greenhouse to the Bussey Institution will make possible a closer cooperation than has been possible heretofore. The Arnold Arboretum is the only one in the United States which is connected with a university and can draw upon the specialists in its faculty for scientific help.
>
> Already we have in view for these courses two men in the first rank in their fields, although no definite arrangements have been made to secure their services. If we succeed in getting the right man for the course in plant pathology this work will begin about July 1. Dr. East, at the Bussey Institution, will supervise the work on genetics. We shall also add to the staff another systematic botanist whose field will cover the woody plants of tropical America.
>
> A tentative plan offers to advanced research students at the Arboretum an opportunity to carry on special work in dendrological directions. Inducements will be offered to persuade able men to take their doctor's degree in dendrology at the Arboretum, as there is great need for more experts in this field who are interested in developing quicker-growing trees and improved woods better suited to the manufacturing needs of the future.
>
> The assembling of rare species and varieties of plants will be continued, of course, so that the Arboretum may remain in the forefront of gardens of its type.
>
> The Arboretum is looking eagerly toward Spanish Honduras, at present, as very little is known of its plant life because it is a difficult country for the white man to explore. It is hoped to send an expedition there in the near future, as anything found there would be exceedingly valuable from a botanical point of view.